ERDC/EL TR-03-3

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20030604 112

Wetlands Research Program

A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Low-Gradient, Blackwater Riverine Wetlands in Peninsular Florida

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January 2003

Environmental Laboratory

Wetlands Research Program

ERDC/EL TR-03-3
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A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Low-Gradient, Blackwater Riverine Wetlands in Peninsular Florida

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Final report

Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000

Under Work Unit 32985

Corps of Engineers Research Report Summary, January 2003

Assessing Wetland Functions

A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Low-Gradient, Blackwater Riverine Wetlands in Peninsular Florida (ERDC/EL TR-03-3)

ISSUE: Section 404 of the Clean Water Act directs the U.S. Army Corps of Engineers to administer a regulatory program for permitting the discharge of dredged or fill material in the "waters of the United States." As part of the permit review process, the impact of discharging dredged or fill material on wetland functions must be assessed. On 16 August 1996, a National Action Plan to Implement the Hydrogeomorphic Approach (NAP) for developing Regional Guidebooks to assess wetland functions was published. This report is one of a series of Regional Guidebooks that will be published in accordance with the National Action Plan.

RESEARCH OBJECTIVE: The objective of this research was to develop a Regional Guidebook for assessing the functions of low-gradient, blackwater riverine wetlands in peninsular Florida in the context of the Section 404 Regulatory Program.

SUMMARY: The Hydrogeomorphic (HGM) Approach is a collection of concepts and methods for developing functional indices, and subsequently using them to assess the capacity of a wetland to perform functions relative to similar wetlands in a region. The approach was initially designed to be used in the context of the Clean Water Act Section 404 Regulatory Program permit review sequence to consider alternatives, minimize impacts, assess unavoidable project impacts, determine mitigation requirements, and monitor the success of mitigation projects. However, a variety of other potential applications for the approach have been identified, including determining minimal effects under the Food Security Act, designing mitigation projects, and managing wetlands.

This report uses the HGM Approach to develop a Regional Guidebook for assessing the functions of selected bottomland hardwood forests in the low-gradient, blackwater riverine wetlands in peninsular Florida.

AVAILABILITY OF REPORT: The report is available at either of the following Web sites: *http://www.wes.army.mil/el/wetlands/wlpubs.html* or *http://libweb.wes.army.mil/index.htm.* The report is also available on Interlibrary Loan Service from the U.S. Army Engineer Research and Development Center (ERDC) Research Library, telephone (601) 634-2355, under the terms described at *http://libweb.wes.army.mil/lib/library.htm.*

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Preface

This Regional Guidebook was authorized by Headquarters, U.S. Army Corps of Engineers (HQUSACE), as part of the Characterization and Restoration of Wetlands Research Program (CRWRP). It is published as an Operational Draft for field testing for a 2-year period. Comments should be submitted via the Internet at the following address: *http://www.wes.army.mil/el/wetlands/hgmhp.html.* Written comments should be addressed to Department of the Army, Research and Development Center, CEERD-EE-W, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199.

The work was performed under Work Unit 32985, "Technical Development of HGM," for which Dr. Ellis J. Clairain, Jr., Environmental Laboratory (EL), Vicksburg, MS, U.S. Army Engineer Research and Development Center (ERDC), was the Principal Investigator. Mr. Dave Mathis, CERD-C, was the CRWRP Coordinator at the Directorate of Research and Development, HQUSACE; Ms. Colleen Charles, CECW-OR, served as the CRWRP Technical Monitor's Representative; Mr. Glenn G. Rhett, EL, Vicksburg, MS, ERDC, was the Ecosystem Management and Restoration Research Program Manager; and Dr. Clairain was the Task Area Manager.

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Financial support was provided by the Florida Department of Transportation and ERDC. Gary Evink, Josh Boan, and Buddy Clairain provided

encouragement during the preparation of this report. Members of staff and management of the Southwest Florida Water Management District, St. Johns River Water Management District, U.S. Army Engineer District, Jacksonville, Region IV of the U.S. Environmental Protection Agency, University of South Florida, Hillsborough County Environmental Protection Commission, Pinellas County Department of Environmental Management, University of South Florida, and the Tampa Office of the United States Geological Survey allowed personnel to spend time and resources in the development of this report. Gwendolyn Stephenson, Pete Rossi, and Fred Webb, Hillsborough Community College, provided administrative assistance, support, and site access. Rhonda Evans and Chris Noble assisted in the planning stages for field testing and in the field. Jenine Callahan, Agrifros Industries; Robert Kluson, Florida Institute of Phosphate Research; Ted Rochow, Clark Hull, Ken Kramer, Karen Gruenhagen, Robert Maglievaz and others from the Southwest Florida Water Management District; Mark Latch, Florida Department of Environmental Protection; Beth Wertschneg, C.F. Industries; Phillip Evans, Rob Heath, and Debbie Butts, Hillsborough County Parks and Recreation; Candi Peterson, Mobile Corporation; and Ken Stay, Pasco County Parks and Recreation gave permission to access riverine sites and in some instances provided site maps and transport. The Soil and Water Science Department, University of Florida, provided the characterization data for selected Florida soils. David Welker supplied statistical advice and help in document automation. The field work and data compilation would not have been completed without the diligent and cheerful assistance of Allan Dyer. Student field assistants from the University of South Florida and Hillsborough Community College assisted, especially Norman Meeks, Katie Currie, Alice Ketron, Jennifer Huff, and Robbin Miske. Bruce Hanson and Dick Wunderlin identified difficult plants. Ken Lackman, NRCS of Tampa, provided helpful comments on the guidebook.

At the time of publication of this report, Dr. James R. Houston was Director of ERDC, and COL John W. Morris III, EN, was Commander and Executive Director.

This report should be cited as follows:

Uranowski, C., Lin, Z., DelCharco, M., Huegel, C., Garcia, J., Bartsch, I., Flannery, M. S., Miller, S. J., Bacheler, J., and Ainslie, W. (2003). "A Regional Guidebook for applying the hydrogeomorphic approach to assessing wetland functions of low-gradient, blackwater riverine wetlands in peninsular Florida," ERDC/EL TR-03-3, U.S. Army Engineer Research and Development Center, Vicksburg, MS.

1 Introduction

Background

The Hydrogeomorphic (HGM) Approach is a collection of concepts and methods for developing functional indices and subsequently using them to assess the capacity of a wetland to perform functions relative to similar wetlands in a region. The approach was initially designed to be used in the context of the Clean Water Act Chapter 404 Regulatory Program permit review sequence to consider alternatives, minimize impacts, assess unavoidable project impacts, determine mitigation requirements, and monitor the success of mitigation projects. However, a variety of other potential applications for the approach have been identified, including determining minimal effects under the Food Security Act, designing mitigation projects, and managing wetlands.

On August 16, 1996, a National Action Plan (NAP) to Implement the Hydrogeomorphic Approach was published (National Interagency Implementation Team 1996). The NAP was developed cooperatively by the U.S. Army Corps of Engineers (USACE), U.S. Environmental Protection Agency (USEPA), Natural Resources Conservation Service (NRCS), Federal Highways Administration (FHWA), and U.S. Fish and Wildlife Service (USFWS). Publication of the NAP was designed to outline a strategy and promote the development of Regional Guidebooks for assessing the functions of Regional Wetland subclasses using the HGM Approach; solicit the cooperation and participation of Federal, State, and local agencies, academia, and the private sector in this effort; and update the status of Regional Guidebook development.

The sequence of tasks necessary to develop a Regional Guidebook outlined in the NAP was used to develop this Regional Guidebook (see "Development Phase" in Chapter 2). The National Riverine Guidebook (Brinson et al. 1995) and the *Regional Guidebook for Assessing the Functions of Low-Gradient, Riverine Wetlands in Western Kentucky* (Ainslie et al. 1999) served as starting points for this Regional Guidebook. Guidebook development workshops were conducted monthly at Tampa, FL, from December 1998 through April 1999. The workshops were attended by hydrologists, biogeochemists, soil scientists, wildlife biologists, and plant

ecologists from the public, private, and academic sectors with extensive knowledge of riverine, low-gradient, blackwater stream bottomland hardwood forest wetlands in peninsular Florida. Based on the results of the workshop in Kentucky (May 21-24, 1996) and the workshops held in Tampa, a regional wetland subclass was defined and characterized, a reference domain was defined, wetland functions were selected, model variables were identified, and conceptual assessment models were developed. Subsequently, field work was conducted to collect data from reference wetlands. These were then used to revise and calibrate the conceptual assessment models. A draft version of this Regional Guidebook was then subjected to several rounds of peer review and revised into the present version.

Objectives

The objectives of this Regional Guidebook are to (a) characterize the low-gradient, riverine blackwater stream bottomland hardwood forest wetlands in the peninsular Florida reference domain, (b) provide the rationale used to select functions for the regional subclass, (c) provide the rationale used to select model variables and metrics, (d) provide the rationale used to develop assessment models, and (e) provide information from reference wetlands and document its use in calibrating model variables and assessment models, and (f) outline the necessary protocols for applying the functional indices to the assessment of wetland functions.

Organization

This report is organized in the following manner: Chapter 1 provides the background, objectives, and organization of the document. Chapter 2 provides a brief overview of the major components of the HGM Approach and the Development and Application Phases required to implement the approach. Chapter 3 characterizes the Low-Gradient, Riverine Blackwater Stream Bottomland Hardwood Forest Subclass in peninsular Florida in terms of geographical extent, climate, geomorphic setting, hydrology, vegetation, soils, and other factors that influence wetland functions. Chapter 4 discusses each of the wetland functions, model variables, and functional indices. This discussion includes a definition of the function, a quantitative, independent measure of the function for the purposes of validation, a description of the wetland ecosystem and landscape characteristics that influence the function, a definition and description of model variables used to represent these characteristics in the assessment model, a discussion of the assessment model used to derive the functional index, and an explanation of the rationale used to calibrate the index with reference wetland data. Chapter 5 outlines the steps of the assessment protocol for conducting a functional assessment of Low-Gradient, Riverine Blackwater Stream Bottomland Hardwood Forest Wetlands in peninsular Florida. Appendix A is a

glossary of terms. Appendix B provides summaries of functions, assessment models, variables, variable measures, and copies of the field forms needed to collect field data. Appendix C provides expanded discussions on how to measure selected assessment variables. Appendix D contains the data collected at reference wetlands. Appendix E gives directions for using the automatic worksheet.

While it is possible to assess the functions of Low-Gradient, Riverine Blackwater Stream Bottomland Hardwood Forest Wetlands in peninsular Florida using only the information contained in Chapter 5 and Appendix B, it is suggested that potential users familiarize themselves with the information in Chapters 2-4 prior to conducting an assessment.

2 Overview of the Hydrogeomorphic Approach

As stated in Chapter 1, the HGM Approach is a collection of concepts and methods for developing functional indices and subsequently using them to assess the capacity of a wetland to perform functions relative to similar wetlands in a region. The HGM Approach includes four integral components: (a) the HGM Classification; (b) reference wetlands; (c) assessment models/functional indices; and (d) assessment protocols. During the Development Phase of the HGM Approach, these four components are integrated into a Regional Guidebook for assessing the functions of a regional wetland subclass. Subsequently during the Application Phase, end users, following the assessment protocols outlined in the Regional Guidebook, assess the functional capacity of selected wetlands. Each of the components of the HGM Approach and the Development and Application Phases are discussed in this chapter. More extensive treatment of these topics can be found in Brinson (1993a), Brinson et al. (1995), Brinson (1995a), Brinson (1995b), Brinson et al. (1996), Smith et al. (1995), Brinson et al. (1998) Clairain (2002), Davis (Chapter 5, Chapter 8, in preparation), Hauer and Smith (1998), Smith (2001), Smith (in preparation), Smith and Wakeley (2001), and Wakeley and Smith (2001).

Hydrogeomorphic Classification

Wetland ecosystems share a number of common attributes including relatively long periods of inundation or saturation, hydrophytic vegetation, and hydric soils. In spite of these common attributes, wetlands occur under a wide range of climatic, geologic, and physiographic situations, and exhibit a wide range of physical, chemical, and biological characteristics and processes (Ferren, Fiedler, and Leidy 1996; Ferren et al. 1996a,b; Mitsch and Gosselink 1993; Cowardin et al. 1979). The variability of wetlands makes it challenging to develop assessment methods that are both accurate (i.e., sensitive to significant changes in function) and practical (i.e., can be

completed in the relatively short time frame available for conducting assessments). Existing "generic" methods, designed to assess multiple wetland types throughout the United States, are relatively rapid, but lack the resolution necessary to detect significant changes in function. However, one way to achieve an appropriate level of resolution within the available time frame is to reduce the level of variability exhibited by the wetlands being considered (Smith et al. 1995).

The HGM Classification was developed specifically to accomplish this task (Brinson 1993a). It identifies groups of wetlands that function similarly using three criteria that fundamentally influence how wetlands function: geomorphic setting, water source, and hydrodynamics. Geomorphic setting refers to the landform and position of the wetland in the landscape. Water source refers to the primary water source in the wetland such as precipitation, overbank floodwater, or groundwater. Hydrodynamics refers to the level of energy and the direction that water moves in the wetland. Based on these three criteria any number of "functional" wetland groups can be identified at different spatial or temporal scales. For example, at a continental scale Brinson (1993a) identified five hydrogeomorphic wetland classes. These were later expanded to the seven classes described in Table 1 (Smith et al. 1995). In many cases, the level of variability in wetlands encompassed by a continental scale hydrogeomophic class is still too great to develop assessment models that can be rapidly applied while being sensitive enough to detect changes in function at a level of resolution appropriate to the 404 review process. For example, at a continental geographic scale the depression class includes wetlands as diverse as California vernal pools (Zedler 1987), prairie potholes in North and South Dakota (Kantrud, Krapu and Swanson 1989; Hubbard 1988), playa lakes in the high plains of Texas (Bolen, Smith, and Schramm 1989), kettles in New England, and cypress domes in Florida (Kurz and Wagner 1953; Ewel and Odum 1984).

To reduce both inter- and intra-regional variability the three classification criteria are applied at a smaller, regional geographic scale to identify regional wetland subclasses. In many parts of the country existing wetland classifications can serve as a starting point for identifying these regional subclasses (Stewart and Kantrud 1971; Golet and Larson 1974; Wharton et al. 1982; Ferren, Fiedler, and Leidy 1996; Ferren et al. 1996a,b). Regional subclasses, like the continental classes, are distinguished on the basis of geomorphic setting, water source, and hydrodynamics. In addition, certain ecosystem or landscape characteristics may also be useful for distinguishing regional subclasses in certain regions. For example, depression subclasses might be based on water source (i.e., groundwater versus surface water) or the degree of connection between the wetland and other surface waters (i.e., the flow of surface water in or out of the depression through defined channels). Tidal fringe subclasses might be based on salinity gradients. Slope subclasses might be based on the degree of slope, landscape position, the source of water (i.e., throughflow versus groundwater), or other factors. Riverine subclasses might be based on water source, position in the watershed, stream order, watershed size, channel gradient, or floodplain width. Examples of potential regional subclasses are shown in

Table 2 and in Smith et al. (1995) and Rheinhardt, Brinson, and Farley (1997).

Regional Guidebooks include a thorough characterization of the regional wetland subclass in terms of its geomorphic setting, water sources, hydrodynamics, vegetation, soil, and other features that were taken into consideration during the classification process.

Table 1
Hydrogeomorphic Wetland Classes at the Continental Scale

HGM Wetland Class	Definition
Depression	Depression wetlands occur in topographic depressions (i.e., closed elevation contours) that allow the accumulation of surface water. Depression wetlands may have any combination of inlets and outlets or lack them completely. Potential water sources are precipitation, overland flow, streams, or groundwater/interflow from adjacent uplands. The predominant direction of flow is from the higher elevations toward the center of the depression. The predominant hydrodynamics are vertical fluctuations that range from diurnal to seasonal. Depression wetlands may lose water through evapotranspiration, intermittent or perennial outlets, or recharge to groundwater. Prairie potholes, playa lakes, vernal pools, and cypress domes are common examples of depression wetlands.
Tidal Fringe	Tidal fringe wetlands occur along coasts and estuaries and are under the influence of sea level. They intergrade landward with riverine wetlands where tidal current diminishes and river flow becomes the dominant water source. Additional water sources may be groundwater discharge and precipitation. The interface between the tidal fringe and riverine classes is where bidirectional flows from tides dominate over unidirectional flows controlled by floodplain slope of riverine wetlands. Because tidal fringe wetlands frequently flood and water table elevations are controlled mainly by sea surface elevation, tidal fringe wetlands seldom dry for significant periods. Tidal fringe wetlands lose water by tidal exchange, by overland flow to tidal creek channels, and by evapotranspiration. Organic matter normally accumulates in higher elevation marsh areas where flooding is less frequent and the wetlands are isolated from shoreline wave erosion by intervening areas of low marsh. *Spartina alterniflora* salt marshes are a common example of tidal fringe wetlands.
Lacustrine Fringe	Lacustrine fringe wetlands are adjacent to lakes where the water elevation of the lake maintains the water table in the wetland. In some cases, these wetlands consist of a floating mat attached to land. Additional sources of water are precipitation and groundwater discharge, the latter dominating where lacustrine fringe wetlands intergrade with uplands or slope wetlands. Surface water flow is bidirectional, usually controlled by water-level fluctuations resulting from wind or seiche. Lacustrine wetlands lose water by flow returning to the lake after flooding and evapotranspiration. Organic matter may accumulate in areas sufficiently protected from shoreline wave erosion. Unimpounded marshes bordering the Great Lakes are an example of lacustrine fringe wetlands.
Slope	Slope wetlands occur in association with the discharge of groundwater to the land surface or sites with saturated overland flow with no channel formation. They normally occur on sloping land ranging from slight to steep. The predominant source of water is groundwater or interflow discharging at the land surface. Precipitation is often a secondary contributing source of water. Hydrodynamics are dominated by downslope unidirectional water flow. Slope wetlands can occur in nearly flat landscapes if groundwater discharge is a dominant source to the wetland surface. Slope wetlands lose water primarily by saturated subsurface flows, surface flows, and by evapotranspiration. Slope wetlands may develop channels, but the channels serve only to convey water away from the slope wetland. Slope wetlands are distinguished from depression wetlands by the lack of a closed topographic depression and the predominance of the groundwater/interflow water source. Fens are a common example of slope wetlands.
Mineral Soil Flats	Mineral soil flats are most common on interfluves, extensive relic lake bottoms, or large floodplain terraces where the main source of water is precipitation. They receive virtually no groundwater discharge, which distinguishes them from depressions and slopes. Dominant hydrodynamics are vertical fluctuations. Mineral soil flats lose water by evapotranspiration, overland flow, and seepage to underlying groundwater. They are distinguished from flat upland areas by their poor vertical drainage due to impermeable layers (e.g., hardpans), slow lateral drainage, and low hydraulic gradients. Mineral soil flats that accumulate peat can eventually become organic soil flats. They typically occur in relatively humid climates. Pine flatwoods with hydric soils are an example of mineral soil flat wetlands.

(Continued)

Table 1 (Concluded)	
HGM Wetland Class	**Definition**
Organic Soil Flats	Organic soil flats, or extensive peatlands, differ from mineral soil flats in part because their elevation and topography are controlled by vertical accretion of organic matter. They occur commonly on flat interfluves, but may also be located where depressions have become filled with peat to form a relatively large flat surface. Water source is dominated by precipitation, while water loss is by overland flow and seepage to underlying groundwater. They occur in relatively humid climates. Raised bogs share many of these characteristics but may be considered a separate class because of their convex upward form and distinct edaphic conditions for plants. Portions of the Everglades and northern Minnesota peatlands are examples of organic soil flat wetlands.
Riverine	Riverine wetlands occur in floodplains and riparian corridors in association with stream channels. Dominant water sources are overbank flow from the channel or subsurface hydraulic connections between the stream channel and wetlands. Additional sources may be interflow, overland flow from adjacent uplands, tributary inflow, and precipitation. When overbank flow occurs, surface flows down the floodplain may dominate hydrodynamics. In headwaters, riverine wetlands often intergrade with slope, depressional, poorly drained flat wetlands, or uplands as the channel (bed) and bank disappear. Perennial flow is not required. Riverine wetlands lose surface water via the return of floodwater to the channel after flooding and through surface flow to the channel during rainfall events. They lose subsurface water by discharge to the channel, movement to deeper groundwater (for losing streams), and evapotranspiration. Peat may accumulate in off-channel depressions (oxbows) that have become isolated from riverine processes and subjected to long periods of saturation from groundwater sources. Bottomland hardwoods on floodplains are an example of riverine wetlands.

Table 2
Potential Regional Wetland Subclasses in Relation to Geomorphic Setting, Dominant Water Source, and Hydrodynamics

			Potential Regional Wetland Subclasses	
Geomorphic Setting	**Dominant Water Source**	**Dominant Hydrodynamics**	**Eastern USA**	**Western USA/Alaska**
Depression	Groundwater or interflow	Vertical	Prairie pothole marshes, Carolina bays	California vernal pools
Fringe (tidal)	Ocean	Bidirectional, horizontal	Chesapeake Bay and Gulf of Mexico tidal marshes	San Francisco Bay marshes
Fringe (lacustrine)	Lake	Bidirectional, horizontal	Great Lakes marshes	Flathead Lake marshes
Slope	Groundwater	Unidirectional, horizontal	Fens	Avalanche chutes
Flat (mineral soil)	Precipitation	Vertical	Wet pine flatwoods	Large playas
Flat (organic soil)	Precipitation	Vertical	Peat bogs; portions of Everglades	Peatlands over permafrost
Riverine	Overbank flow from channels	Unidirectional, horizontal	Bottomland hardwood forests	Riparian wetlands

Reference Wetlands

Reference wetlands are the wetland sites selected to represent the range of variability that occurs in a regional wetland subclass as a result of natural processes and disturbance (e.g., succession, channel migration, fire, erosion, and sedimentation) as well as human alteration. The reference domain is the geographic area occupied by the reference wetlands (Smith et al. 1995). Ideally, the geographic extent of the reference domain will mirror the geographic area encompassed by the regional wetland subclass; however, this is not always possible due to time and resource constraints.

Reference wetlands serve several purposes. First, they establish a basis for defining what constitutes a characteristic and sustainable level of function across the suite of functions selected for a regional wetland subclass. Second, they establish the range and variability of conditions exhibited by model variables, and provide the data necessary for calibrating model variables and assessment models. Finally, they provide a concrete, physical representation of wetland ecosystems that can be repeatedly observed and measured.

Reference standard wetlands are the subset of reference wetlands that perform the suite of functions selected for the regional subclass at a level that is characteristic in the least altered wetland sites in the least altered landscapes. Table 3 outlines the terms used by the HGM Approach in the context of reference wetlands.

Table 3
Reference Wetland Terms and Definitions

Term	Definition
Reference domain	The geographic area from which reference wetlands representing the regional wetland subclass are selected (Smith et al. 1995).
Reference wetlands	A group of wetlands that encompass the known range of variability in the regional wetland subclass resulting from natural processes and disturbance and from human alteration.
Reference standard wetlands	The subset of reference wetlands that perform a representative suite of functions at a level that is both sustainable and characteristic of the least human-altered wetland sites in the least human-altered landscapes. By definition, the Functional Capacity Indices for all functions in reference standard wetlands are assigned a 1.0.
Reference standard wetland variable condition	The range of conditions exhibited by model variables in reference to standard wetlands. By definition, reference standard conditions receive a variable subindex score of 1.0.
Site potential (mitigation project context)	The highest level of function possible, given local constraints of disturbance history, land use, or other factors. Site potential may be less than or equal to the levels of function in reference standard wetlands of the regional wetland subclass.
Project target (mitigation project context)	The level of function identified or negotiated for a restoration or creation project.
Project standards (mitigation project context)	Performance criteria and/or specifications used to guide the restoration or creation activities toward the project target. Project standards should specify reasonable contingency measures if the project target is not being achieved.

Assessment Models and Functional Indices

In the HGM Approach, an assessment model is a simple representation of a function performed by a wetland ecosystem. It defines the relationship between one or more characteristics or processes of the wetland ecosystem or surrounding landscape and the functional capacity of a wetland ecosystem. Functional capacity is simply the ability of a wetland to perform a function compared to the level of performance in reference standard wetlands.

Model variables represent the characteristics of the wetland ecosystem and surrounding landscape that influence the capacity of a wetland ecosystem to perform a function. Model variables are ecological attributes that consist of five components (Schneider 1994): (a) a name; (b) a symbol; (c) a measure of the variable and procedural statement for quantifying or qualifying the measure directly, or calculating it from other measurements; (d) a set of values (i.e., numbers, categories, or numerical estimates (Leibowitz and Hyman 1997) that are generated by applying the procedural statement; and (e) units on the appropriate measurement scale. Table 4 provides several examples.

Table 4
Components of a Model Variable

Name (Symbol)	Measure/Procedural Statement	Resulting Values	Units (Scale)
Redoximorphic Features (V_{REDOX})	Status of redoximorphic features/ visual inspection of soil profile for redoximorphic features	Present / Absent	Unitless (nominal scale)
Floodplain Roughness (V_{ROUGH})	Manning's Roughness Coefficient n. Observe wetland characteristics to determine adjustment values for roughness component to add to base value	0.01 0.1 0.21	Unitless (interval scale)
Tree Biomass (V_{TBA})	Tree basal area/measure diameter of trees in sample plots (cm), convert to area (m^2), and extrapolate to per-hectare basis	5 12.8 36	m^2/ha (ratio scale)

Model variables occur in a variety of states or conditions in reference wetlands. The state or condition of the variable is denoted by the value of the measure of the variable. For example, the variable tree basal area, used as an estimate of tree biomass, could be large or small. Similarly, recurrence interval, the measure of overbank flood frequency variable, could be frequent or infrequent. Based on its condition (i.e., value of the metric), model variables are assigned a variable subindex. When the condition of a variable is within the range of conditions exhibited by reference standard wetlands, a variable subindex of 1.0 is assigned. As the condition deflects from the reference standard condition (i.e., the range of conditions in which the variable occurs in reference standard wetland), the variable subindex is assigned based on the defined relationship between model variable condition and functional capacity. As the condition of a variable deviates from

the conditions exhibited in reference standard wetlands, it receives a progressively lower subindex reflecting its decreasing contribution to functional capacity. In some cases, the variable subindex drops to zero. For example, when no trees are present, the subindex for tree basal area is zero; in other cases, the subindex for a variable never drops to zero. For example, regardless of the condition of a site, Manning's roughness coefficient n will always be greater than zero.

Model variables are combined in an assessment model to produce a Functional Capacity Index (FCI) that ranges from 0.0 to 1.0. The FCI is a measure of the functional capacity of a wetland relative to reference standard wetlands in the reference domain. Wetlands with an FCI of 1.0 perform the function at a level that is characteristic of reference standard wetlands. As the FCI decreases, it indicates the capacity of the wetland to perform the function is less than that which is characteristic of reference standard wetlands.

Assessment Protocol

The final component of the HGM Approach is the assessment protocol. The assessment protocol is a series of tasks, along with specific instructions, that allow the end user to assess the functions of a particular wetland area using the functional indices in the Regional Guidebook. The first task is characterization, which involves describing the wetland ecosystem and the surrounding landscape, describing the proposed project and its potential impacts, and identifying the wetland areas to be assessed. The second task is collecting the field data for model variables. The final task is analysis, which involves calculation of functional indices.

Development Phase

The Development Phase of the HGM Approach is ideally carried out by an interdisciplinary team of experts known as the Assessment or A-Team. The product of the Development Phase is a Regional Guidebook for assessing the functions of a specific regional wetland subclass (Figure 1). In developing a Regional Guidebook, the A-Team will complete the following major tasks. After organization and training, the first task of the A-Team is to classify the wetlands within the region of interest into regional wetland subclasses using the principles and criteria of the Hydrogeomorphic Classification (Brinson 1993a; Smith et al. 1995). Next, focusing on the specific regional wetland subclass selected, the A-Team develops an ecological characterization or functional profile of the subclass. The A-Team then identifies the important wetland functions, conceptualizes assessment models, identifies model variables to represent the characteristics and processes that influence each function, and defines metrics for quantifying

model variables. Next, reference wetlands are identified to represent the range of variability exhibited by the regional subclass. Field data are then collected from the reference wetlands and used to calibrate model variables, and verify the conceptual assessment models. Finally, the A-Team develops the assessment protocols necessary for regulators, managers, consultants, and other end users to apply the indices to the assessment of wetland functions. The following list provides the detailed steps involved in the general sequence described:

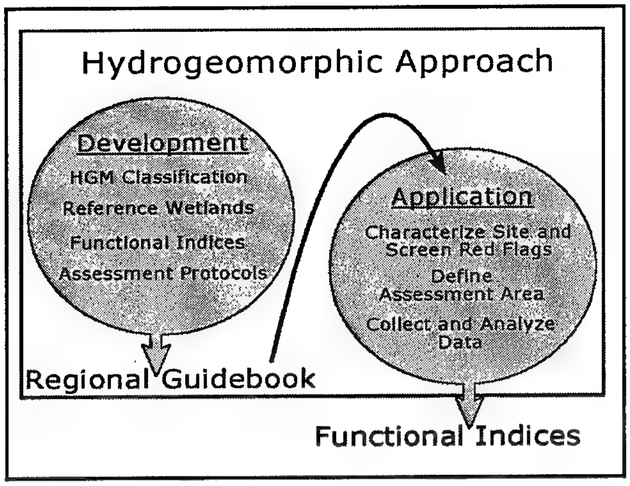

Figure 1. Development and Application Phases of the HGM Approach

Task 1: Organize the A-Team
- A. Identify A-Team members
- B. Train A-Team in the HGM Approach

Task 2: Select and Characterize Regional Wetland Subclass
- A. Identify/prioritize regional wetland subclasses
- B. Select regional wetland subclass and define reference domain
- C. Initiate literature review
- D. Develop preliminary characterization of regional wetland subclass
- E. Identify and define wetland functions

Task 3: Select Model Variables and Metrics and Construct Conceptual Assessment Models
- A. Review existing assessment models
- B. Identify model variables and metrics
- C. Define initial relationship between model variables and functional capacity
- D. Construct conceptual assessment models for deriving FCIs
- E. Complete Precalibrated Draft Regional Guidebook (PDRG)

Task 4: Conduct Peer Review of PDRG
- A. Distribute PDRG to peer reviewers
- B. Conduct interdisciplinary, interagency workshop of PDRG
- C. Revise PDRG to reflect peer review recommendations
- D. Distribute revised PDRG to peer reviewers for comment
- E. Incorporate final comments from peer reviewers on revisions into the PDRG

Task 5: Identify and Collect Data from Reference Wetlands
- A. Identify reference wetland field sites
- B. Collect data from reference wetland field sites
- C. Analyze reference wetland data

Task 6: Calibrate and Field Test Assessment Models
- A. Calibrate model variables using reference wetland data
- B. Verify and validate (optional) assessment models
- C. Field test assessment models for repeatability and accuracy
- D. Revise PDRG based on calibration, verification, validation (optional), and field testing results into a Calibrated Draft Regional Guidebook (CDRG)

Task 7: Conduct Peer Review and Field Test of CDRG
- A. Distribute CDRG to peer reviewers
- B. Field test CDRG
- C. Revise CDRG to reflect peer review and field test recommendations
- D. Distribute CDRG to peer reviewers for final comment on revisions
- E. Incorporate peer reviewers' final comments on revisions
- F. Publish Operational Draft Regional Guidebook (ODRG)

Task 8: Technology Transfer
- A. Train end users in the use of the ODRG
- B. Provide continuing technical assistance to end users of the ODRG

Application Phase

The Application Phase involves two steps. The first is using the assessment protocols outlined in the Regional Guidebook to carry out the following tasks (Figure 1).

a. Define assessment objectives.

b. Characterize the project site.

c. Screen for red flags.

d. Define the Wetland Assessment Area.

e. Collect field data.

f. Analyze field data.

The second step involves applying the results of the assessment, the FCI, to the appropriate decision-making processes of the permit review sequence, such as alternatives analysis, minimization, assessment of unavoidable impacts, determination of compensatory mitigation, design and monitoring of mitigation, comparison of wetland management alternatives

or results, determination of restoration potential, or identification of acquisition or mitigation sites.

3 Characterization of Riverine Class, Low-Gradient, Blackwater Stream Bottomland Hardwood Forest Wetlands of Peninsular Florida

Regional Wetland Subclass and Reference Domain

The reference domain is defined as all wetlands within a specified geographic region that belong to a single HGM subclass (Smith et al. 1995). The reference domain for the riverine class, low-gradient, blackwater stream, bottomland hardwood forest wetlands is shown in Figure 2. The reference domain for this subclass consists of those counties in peninsular Florida that are within the Southwest Florida Water Management District. This HGM subclass excludes wetlands that are influenced by tidal waters with salinities of 0.5 ppt or greater.

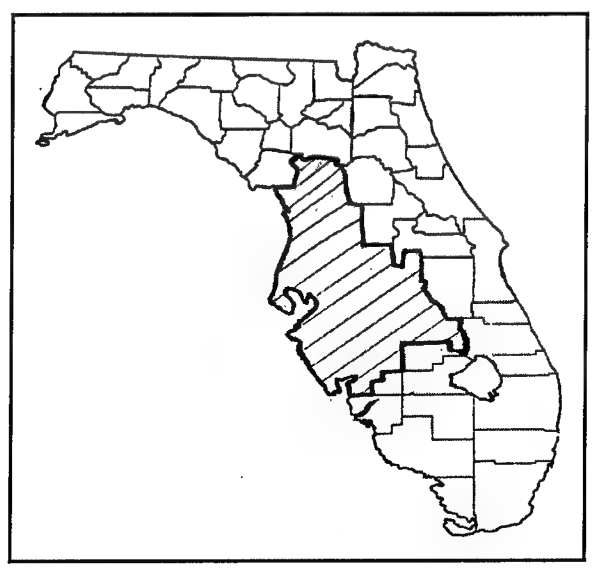

Figure 2. Location of reference domain within the state of Florida

Riparian soil types in the poorly drained floodplains of the Florida Peninsula vary considerably in this extensive reference domain. Nineteen soil series are associated with the floodplains in this reference domain (Table 5). Tree assemblages are also diverse, and numerous species unite to form the distinctive closed canopy.

Table 5
Classification of the Hydric Soils Associated with Bottomland Hardwood Forest Wetlands of Peninsular Florida

Soil Name	Family or Higher Taxonomic Class
Anclote	Sandy, siliceous, hyperthermic Typic Haplaquolls
Astor	Sandy, siliceous, hyperthermic Cumulic Haplaquolls
Basinger	Siliceous, hyperthermic Spodic Psammaquents
Bluff	Fine-loamy, mixed, hyperthermic Typic Haplaquolls
Bradenton	Coarse-loamy, siliceous, hyperthermic Typic Argiaquolls
Chobee	Fine-loamy, siliceous, hyperthermic Typic Argiaquolls
Delray	Loamy, mixed, hyperthermic Grossarenic Argiaquolls
Felda	Loamy, siliceous, hyperthermic Arenic Ochraqualfs
Floridana	Loamy, siliceous, hyperthermic Arenic Argiaquolls
Holopaw	Loamy, siliceous, hyperthermic Grossarenic Ochraqualfs
Iberia	Fine, montmorillonitic, noncalcareous, thermic Vertic Haplaquolls
Malabar	Loamy, siliceous, hyperthermic Grossarenic Ochraqualfs
Manatee	Coarse-loamy, siliceous, hyperthermic Typic Argiaquolls
Nittaw	Fine, montmorillonitic hyperthermic Typic Argiaquolls
Pineda	Loamy, siliceous, hyperthermic Arenic Glossaqualfs
Placid	Sandy, siliceous, hyperthermic Typic Humaquents
Pompano	Siliceous, hyperthermic Typic Psammaquents
Wabasso	Sandy, siliceous, hyperthermic Alfic Hapaquods
Winder	Fine-loamy, siliceous, hyperthermic Typic Glossaqualfs

Source: Soil Surveys of Florida.

Some within the canopy include American elm, basswood, black gum, Carolina ash, cypress, diamond oak, muscle wood, red maple, sweetgum, and water hickory. The greatest land use impacts in this ecoregion are crop and livestock production, housing, industrial and road developments, and phosphate mining. The seasonally or semipermanently forested subclass in this ecoregion represents a wetland type subject to an increase in projected linear impacts from the Florida Department of Transportation projects. Therefore, development of assessment models for this subclass will greatly benefit the Section 404 permitting process for the District.

Potential Geographic Extent of the Regional Subclass

The potential for future expansion of the reference domain and application of this guidebook is an option of the appropriate State, county, and/or Federal permitting agencies.

Characteristics of the Regional Subclass

This Regional Guidebook is designed to be used in riverine, low-gradient, blackwater stream, forested wetlands in peninsular Florida. The riverine bottomland hardwood forest subclass experiences a great amount of wetland permitting activity. Therefore, this subclass received Florida Department of Transportation priority for development of regional assessment models. This subclass is associated typically with first- through fourth-order streams, and has three potential water sources: (a) lateral surface or near-surface transport from overbank flow; (b) infiltration of surface runoff from adjacent landforms facilitated by the characteristically porous sandy soils; and (c) groundwater discharge to the wetland. Floodplains with moderately entrenched streams of this wetland subclass experience flooding (i.e., discharge exceeds channel-full capacity) usually on an annual basis (Clewell 1991). Floodplains with slightly entrenched or anastomosed channels flood more frequently. Flood frequency for both channel types in peninsular Florida is determined by an increase in local rainfall events where overbank flow is locally described as "flashy." Beck (1965) recognizes sand-bottomed streams as the most widely distributed type in Florida. These blackwater, sandy-bottomed rivers are low in suspended sediment loads, usually clear but contain highly colored tannic acid and dissolved organic matter (DOM) derived from detrital remains that drain from depressional wetlands (Wharton et al. 1982) and other vegetative communities within the basin. The inorganic ions of iron and aluminum that complex with DOM are in high concentrations and constitute a ratio of 1:1 in blackwater streams (Wharton et al.1982). The dissolved organic humic and fluvic acids contribute to high total organic carbon concentrations and a low pH (Wharton et al.1982). The forested reaches of this subclass create a habitat complexity that facilitates a high diversity of both terrestrial and aquatic fauna (Estevez, Dixon, and Flannery 1991). Other functions performed by these bottomland hardwood forest stands include strong biogeochemical activity and nutrient cycling (Gregory et al. 1991).

Climate

Because peninsular Florida is completely surrounded by water, maritime climatic zones influence weather patterns far greater than do geographic climatic zones. A twofold increase in frequency of freezing occurs within a short distance inland in northern Florida (Chen and Gerber 1992). Proximity

to the Gulf and Atlantic mitigates the effects of temperature in peninsular Florida whereas these influences are much reduced in the northern panhandle. This temperature distinction marks the superimposed dividing line (Figure 3) between peninsular and continental Florida (Winsberg 1992). Climatic rainfall patterns are similar throughout the state. The dry season occurs usually from October through May with a rainy season from June through October, although a seasonal variation does exist in the northern panhandle region. In the reference domain a secondary peak of winter rainfall ensues (Winsberg 1992). As a result, peak flows occur during the winter and spring in the panhandle and north Florida and during the late summer and early fall farther south in the reference domain. The influence of rainfall patterns causes vegetation, soil types, temperature gradients, and seasonal evapotranspiration rates within the state to vary considerably.

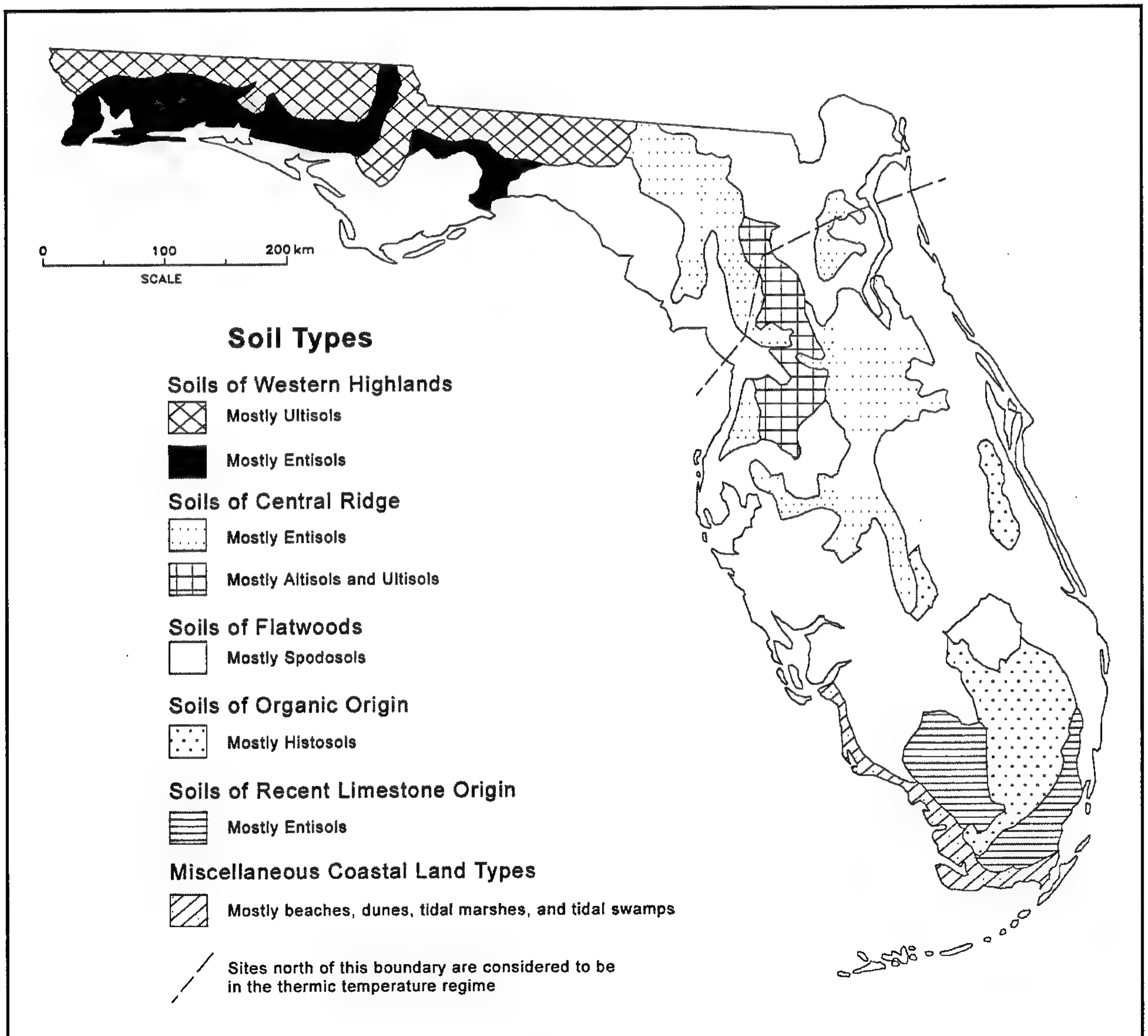

Figure 3. The thermic temperature regime dividing line between peninsular and continental Florida (modified from Carlisle and Watts 2000)

The dividing line (Figure 3) between peninsular and continental Florida is recognized by climatologists as well as by soil scientists (Heath and Conover 1981; Carlisle and Watts 2000). The soils north of this line are in the thermic temperature regime. The mean annual temperature regime, measured at 20 in. (0.5 m) below the surface, maintains at between 59 °F (17.5 °C) to 72° F (22 °C). An approximate 9 °F (5 °C) variability between average summer and winter temperature occurs here. South of this line the soils are considered to be in the hyperthermic temperature regime. Soil temperature 20 in. (0.5 m) below the surface maintains a mean annual of higher than 72 °F (22 °C) with 9 °F (5 °C) variability between average summer and winter temperature (Carlisle and Watts 2000).

Geomorphic setting

The geologic history of the Florida Peninsula has been described by many (Dall and Harris 1892; Chen 1965; Schmidt 1997). The basement of the Florida Peninsula is composed of pre-Mesozoic sedimentary rocks, extrusive and intrusive igneous rocks, and metamorphic rocks (Smith and Lord 1997). The shallow marine currents dominated the shape of the Florida Plateau by the cyclic forces of erosion and deposition. Compaction of calcium and magnesium carbonate sedimentation that occurred from Late Cretaceous to early Oligocene resulted in the formation of the Floridan aquifer (Heatherington and Mueller 1997). The Floridan Aquifer extends into southern South Carolina and ranges through parts of Georgia and Alabama, extending throughout all of Florida.

Tectonic activity during the Neogene to Holocene resulted in the uplift of the Florida Platform. The structural features left by this uplift are named the Ocala Platform and the Peninsular Arch. The topographic relief of these uplifts and the substantial precipitation characteristically received contributed to high runoff (Rosenau et al. 1977). The combined heavy rainfall and high runoff shaped and degraded the marine deposits to form the rivers, their ancient terraces, and the youngest active floodplains of modern Florida (Dury 1977). Florida rivers and their floodplains function distinctly as influenced by many factors other than climate that include topographic aspect and groundwater hydrology, which result in various stream characteristics and wetland types. A marked gradient occurs in streams from the panhandle west decreasing southeasterly. Many rivers in the panhandle are at higher elevations with their origins in Alabama and Georgia and carry significant loads of silt and clays. Conversely, nutrients and dissolved inorganics are usually low from these rivers. The highest concentrations are found in south and east peninsular Florida blackwater rivers of the reference domain (Nordlie 1992). It is the highly conductive sandy soils of the flatwoods that contribute very little to sediment loading in the blackwater streams of peninsular Florida.

Three physiographic districts are found in the subclass reference domain as described by Brooks (1982) (Figure 4). The Ocala Uplift District, to the north, comprises mostly mixed hardwoods, pine flatwoods, and sandhills.

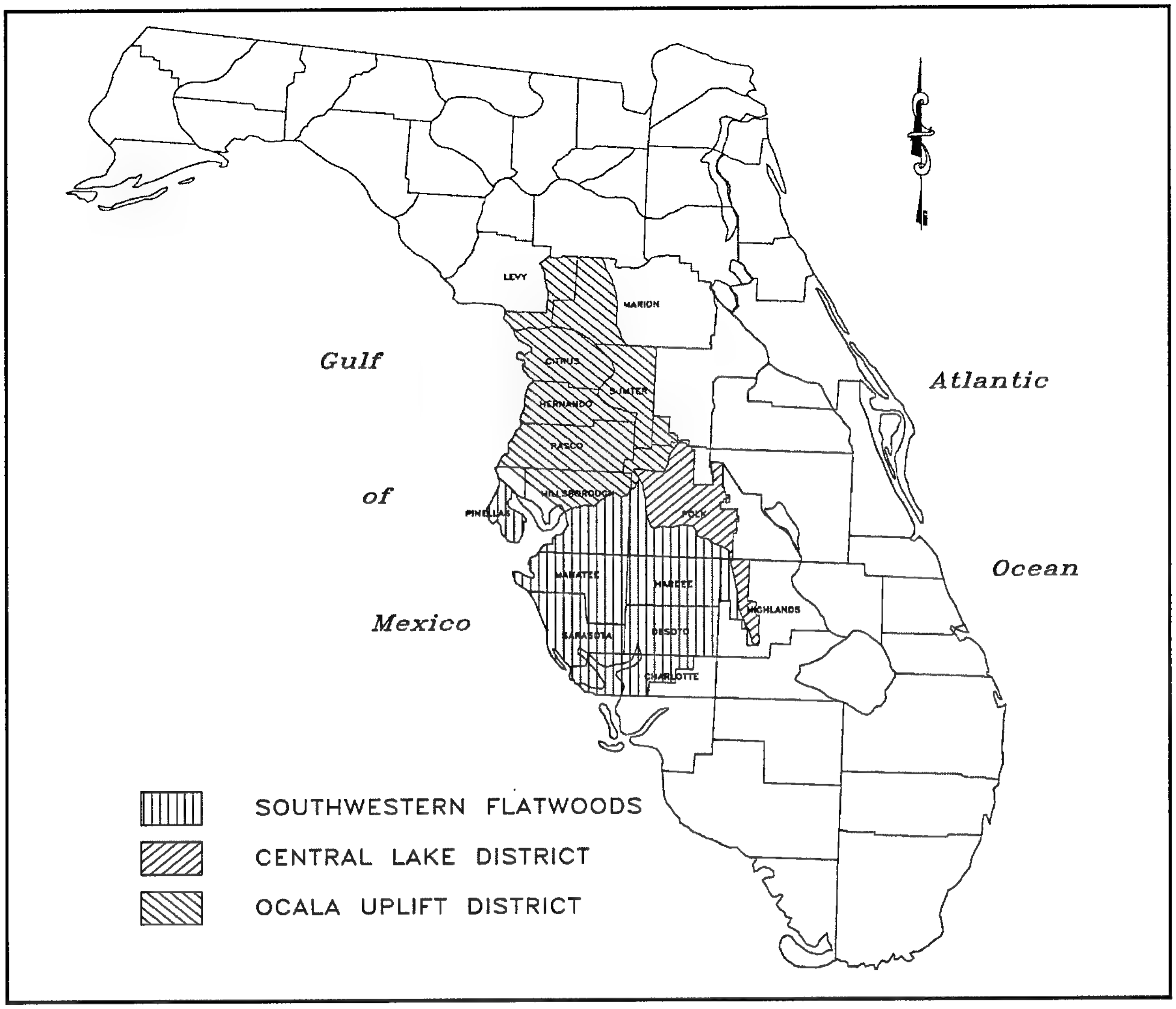

Figure 4. Physiographic map, Southwest Florida Water Management District (modified from Brooks 1982)

In this region the Floridan aquifer is near the surface, and karst landforms dominate. Groundwater discharge and permeability rates are high in this region. Below is the low flat plateau of the Southwestern Flatwoods District consisting mostly of pine flatwoods, prairies, cypress domes, mangroves, and dunes. Flanking the Southwestern Flatwoods District to the east is the Central Lake District. This physiographic region is marked by sandhill karst terrain and sand pine scrub. This district is the main area of recharge for the Floridan Aquifer (Stewart 1980).

Solution sinkholes that formed on near-surface karst terrain dominate in the Ocala Uplift District and the northern portion of the Southwestern Flatwoods District (Brown, Stone, and Carlisle 1992). However, a Miocene orogeny known as the Hawthorn Formation is found at the intersection of all three Districts: the southern border of the Ocala Uplift District, in the northern section of the Southwestern Flatwoods, and in most of the Central Lake District. The Hawthorn formation is a thick impermeable clay layer occurring between the sandy overburden and the underlying limestone. Lower rates

of groundwater discharge and soil permeability result from this occurrence (Brown, Stone, and Carlisle 1992).

The Cowardin/National Wetland Inventory (NWI) system was utilized as a modifier to the hydrogeomorphic classification for vegetation and to some extent for hydrology. The riverine, low-gradient, overbank flooded and groundwater discharge, forested subclass (seasonally and semipermanently flooded forest) contains the palustrine forested vegetative class as described by Cowardin et al. (1979) and mapped by NWI. This geomorphic setting also gives rise to the riverine, low-gradient, anastomosed, herbaceous subclass (semipermanently flooded marsh), which contains the palustrine emergent and scrub-shrub vegetative classes and the forested bottomland hardwood swamp subclass (semipermanently flooded forest), which are frequently found along streams in the study area. The State of Florida has more than 1,700 rivers measuring a combined length of roughly 11,000 miles (17,000 km) (Livingston and Fernald 1991). Low velocity with many strongly meandering stream reaches characterize these flat, sandy-bottomed streams often marked by limestone outcroppings that create riffles and pools (Clewell 1991). The predominant stream type can be classified as Rosgen (1996) C/E type. These streams are indicative of Valley Type X, prevalent in peninsular Florida; marked by gentle slopes and slightly entrenched sinuous channels with broad and sometimes extensive floodplains (Rosgen 1996). The highly stable stream channels of this subclass have a less than 2 percent gradient and exhibit low channel width/depth ratios of less than 12 (Rosgen 1996).

Hydrologic regimes. Typically, peak flows occur in the reference domain floodplains of peninsular Florida during the late summer and early spring when water is supplied to the wetlands primarily from lateral surface and near-surface transport from overbank flooding. Increased winter precipitation during the 1997-98 season resulted in unusually high flows with increased current velocities and overbank flooding. Normally, flow patterns associated with blackwater streams in the reference domain are low in winter months. During normal winters, low flow is maintained and streams are charged during periods of low rainfall by groundwater discharge from the surficial aquifer (Wolfe and Drew 1990).

Peak flooding occurs during the wet season in late summer for the major river systems in the Southwest Florida Water Management District (Flannery 1989). Some of these rivers include the Withlacoochee, Hillsborough, Alafia, Little Manatee, Manatee, Myakka, Peace, Ocklawaha, and Anclote Rivers. Smaller episodic flooding usually occurs in the winter from January through March (Dragovich, Kelly, and Goddell 1968; Flannery 1989). Flooding and river flow are closely correlated to periods of heavy rainfall (Dragovich, Kelly, and Goddell 1968), and water levels usually rise and fall quickly (Ewel 1990). Average flow ranges and total area drained by these rivers are shown in Table 6. The lowest flow averages 2.0 $m^3 s^{-1}$ along the Anclote River and the highest flow averages 45.2 $m^3 s^{-1}$ along the Ocklawaha River. Total area drained by these rivers is 25,423 km^2. The dividing line (Figure 3) between peninsular Florida and continental

Florida is also recognized as a climatic divide contrasting water conditions between the north and south of this line. Streamflow discharge in rivers north of the climatic divide are highest in late winter and early spring in contrast to the rivers south of the line with peak discharges in late summer and early fall (Heath and Conover 1981).

Table 6
Statistics for Selected Waterways in the Reference Domain

River	Drainage, km^2	Average Flow, m^3 s^{-1}	Average Slope, m km^{-1}
Anclote	188	2.0	0.55
Hillsborough	4,962	9.7	0.27
Alafia	105	10.0	
South Prong	350	4.7	
North Prong	277	3.0	
Little Manatee	566	4.8	0.64
Manatee	922	2.2	
Myakka	1,399	7.1	0.34
Peace	5,957	32.7	0.19
Ocklawaha	5,517	45.2	0.13
Withlacoochee	5,180	32.0	0.17

Sources: Nordlie (1992); Wolfe and Drew (1990).

Evapotranspiration rates in Florida average 110 billion gallons (4×10^8 m^3) per day. The highest rates are in the south-central mainland area within the reference domain. The lowest rates occur in the northwestern and panhandle portions of the state and in the Keys (Fernald and Patton 1984). Runoff rates are high, exceeding average precipitation over annual average potential evapotranspiration by 3 to 6 in. (76 to 152 mm) in much of peninsular Florida. Flat terrain, slow drainage over sandy flatwoods, and widespread wetlands are controlling factors for high runoff potential (Fernald and Patton 1984). Channel slopes in the reference domain range from 0.01 percent to 0.07 percent (0.1-0.6 m km^{-1}) in the reference domain (Table 6).

This subclass is characterized by 19 different soil types (Table 5), which are listed as hydric soils on the county hydric soil lists. All 19 soil series consist of deep, nearly level, poorly to very poorly drained soils that have a loamy or a sandy subsoil or are sandy throughout. Permeability is rapid (6-20 in./hr (0.15-0.5 m/hr)) to moderately rapid (2-6 in./hr (0.05-0.15 m/hr)). Slopes are typically less than 2 percent.

Vegetation. Canopy vegetation consists mainly of a mosaic of cypress (*Taxodium* sp.), red maple (*Acer rubrum*), water tupelo (*Nyssa biflora*), sweetgum (*Liquidambar styraciflua*), American elm (*Ulmus americana*), Carolina ash (*Fraxinus caroliniana*), diamond oak (*Quercus laurifolia*), muscle wood (*Carpinus caroliniana*), and water hickory (*Carya aquatica*).

Tree species dominance varies greatly between sites as evidenced by the clinal nature of bottomland hardwood forest where tree diversity can be high, as shown in Table 11, to be discussed in Chapter 4. Subcanopy species such as Virginia willow (*Itea virginica*), swamp dogwood (*Cornus foemina*), walter viburnum (*Viburnium obovatum*), and dwarf palmetto (*Sabal minor*) are common components of this wetland subclass. The heterogeneity of species diversity is greatly characterized by the ground cover vegetation. Upwards of between 30 to 40 species of ground cover vegetation have been identified in a single reference standard wetland (Table 11).

Disturbance/land use. In 1970, bottomland hardwood forests represented 16 percent of the total area of the state of Florida (Turner, Forsythe, and Craig 1981). More recent pressures catalyzed by an extraordinary increase in population have resulted in a disruption of the functions and processes of Florida's lotic ecosystems. The major impacts and losses to riverine wetlands are attributed to channelization, impoundment, industrialization and mining, rapid urbanization, and agricultural activity (Livingston 1991). More than 12 of the 40 major waterways of Florida are partially or completely channelized (Nordlie 1992). At least five of these rivers in the Southwest Florida Water Management District have impoundment reservoirs to provide storage for municipal water supplies or water is directly withdrawn. These withdrawals can significantly reduce freshwater flow during periods of reduced rainfall (Estevez, Dixon, and Flannery 1991). Industrial and wastewater discharge, phosphate mining, and agricultural activities have severely impacted the south-central floodplains (Estevez, Dixon, and Flannery 1991). These activities adversely affect water quality by increasing sedimentation, nutrients, coliform bacteria, toxic metals, and radioactive and synthetic organic compounds to ground and surface waters. However, sedimentation and the effects of erosion by phosphate mining can be minimized if the area is effectively reclaimed.

4 Wetland Functions and Assessment Models

The following functions performed by low-gradient, blackwater stream bottomland hardwood forests in peninsular Florida were selected for assessment:

a. Temporarily Store Surface Water.

b. Maintain Characteristic Subsurface Hydrology.

c. Cycle Nutrients.

d. Remove and Sequester Elements and Compounds.

e. Retain Particulates.

f. Export Organic Carbon.

g. Maintain Characteristic Plant Community.

h. Provide Habitat for Wildlife.

The following sequence is used to present and discuss each of these functions:

a. Definition: defines the function and identifies an independent quantitative measure that can be used to validate the functional index.

b. Rationale for selecting the function: provides the rationale for selecting a function, and discusses onsite and offsite effects that may occur as a result of lost functional capacity.

c. Characteristics and processes that influence the function: describes the characteristics and processes of the wetland and the surrounding landscape that influence the function and lays the groundwork for the description of the model variables.

d. Description of model variables: defines and discusses model variables, and describes how each model variable is measured.

e. Functional Capacity Index: describes the assessment model from which the FCI is derived, and discusses how model variables interact to influence functional capacity.

Function 1: Temporarily Store Surface Water

Definition

Temporary storage of surface water is defined as the capacity of a riverine wetland to temporarily store and convey floodwaters that inundate riverine wetlands during overbank flood events. Most of the water that is stored and conveyed originates from an adjacent stream channel. However, other potential sources of water include (a) precipitation; (b) surface water from adjacent uplands transported to the wetland via surface channels or overland flow; and (c) subsurface water from adjacent uplands transported to the wetland as interflow or shallow groundwater that discharges at the edge or interior of the floodplain. A potential independent quantitative measure for validating the functional index is the volume of water stored per unit area per unit time (m^3/ha/time) at a discharge that is equivalent to the average annual peak event.

Rationale for selecting the function

The capacity of riverine wetlands to temporarily store and convey floodwater has been extensively documented (Dewey and Kropper Engineers 1964; Campbell and Johnson 1975; Dybvig and Hart 1977; Novitski 1978; Thomas and Hanson 1981; Ogawa and Male 1983, 1986; Demissie and Kahn 1993). Many benefits related to the reduction of flood damage occur as a result of wetlands performing the function. For example, wetlands can reduce the velocity of the flood wave and as a result, reduce peak discharge to downstream. Similarly, wetlands can reduce the velocity of water currents and as a result, reduce damage from erosion forces (Ritter, Kochel, and Miller 1995).

In addition to these direct benefits, a number of ecological processes occur in riverine wetlands that depend on the periodic inundation that results from overbank floods. For example, as the velocity of the overbank flow is reduced, inorganic sediments and particulate organic matter settle out of the water column (Nicholas and Walling 1996; Walling, Quine, and He 1992; James 1985; Ritter, Kinsey, and Kauffman 1973). This provides a nutrient subsidy to plant communities on the floodplain, and can contribute to an improvement in the quality of water in streams and rivers (Mitsch, Dorge, and Wienhoff 1979). As floodwater inundates riverine wetlands, it also provides access to floodplain feeding and reproductive areas for fish and other aquatic organisms (Copp 1997; Killgore and Baker 1996; Ross and Baker 1983; Guillory 1979; Welcomme 1979; Gunderson 1968), and serves as a transport mechanism for plant propagules that may be important to the dispersal and regeneration of certain plant species (Johansson, Nilsson, and Nilsson 1996; Nilsson, Gardfjell, and Grelsson 1991; Schneider and Sharitz 1988). Finally, overbank floodwater facilitates the export of particulate and dissolved organic carbon from the riverine wetland to downstream aquatic food webs (Anderson and Sedell 1979; Mulholland and Kuenzler 1979).

Characteristics and processes that influence the function

The characteristics and processes that influence the capacity of a wetland to temporarily store floodwater are related to climate, watershed characteristics, conditions in the stream channel adjacent to the wetland, as well as conditions in the wetland itself. In general, the intensity, duration and areal extent of precipitation events affect the magnitude of the stormflow response. Typically, the higher the intensity, the longer the duration, and greater the areal extent of a particular rainfall event, the greater the flood peak will be. Watershed characteristics such as size and shape, channel and watershed slopes, drainage density, and the presence of wetlands and lakes have a pronounced effect on the stormflow response (Dunne and Leopold 1978; Brooks et al. 1991; Ritter, Kochel, and Miller 1995; Leopold 1994; Patton 1988). The larger the watershed, the greater the volume and peak of streamflow for rainfall events. Watershed shape affects how quickly surface and subsurface flows reach the outlet to the watershed. For example, a round watershed concentrates runoff more quickly than an elongated one and will tend to have higher peak flows. Steeper hillslopes and channel gradients also result in quicker response and higher peak flows. The higher the drainage density (i.e., the sum of all the channel lengths divided by the watershed area), the faster water is concentrated at the watershed outlet and the higher the peak. As the percentage of wetland area and/or reservoirs increases, the greater the flattening effect (attenuation) on the stormflow hydrograph. In general, these climatic and watershed characteristics are the same in a given region and are considered constant for the purposes of rapid assessment. However, site-specific characteristics of riverine wetlands can vary and are the emphasis of this function.

Depth, frequency, and duration of flooding in the riverine wetland are the manifestation of the watershed stormflow response and the characteristics mentioned in the previous paragraph. Conditions conducive to flooding are dictated, to a large degree, by the nature of the stream channel and its floodplain. The morphology of the stream channel and its floodplain reflect the discharges and sediment loads that have occurred in the past. Under naturally stable or unimpacted flow and sediment conditions the stream and its floodplain will eventually achieve equilibrium. Alteration to the stream channel or its watershed may cause instability that results in channel aggradation or degradation and a change in depth, frequency, and duration of overbank flow events (Dunne and Leopold 1978; Rosgen 1994). As the stream channel aggrades, available water storage in the channel decreases, resulting in greater depth, frequency, and duration of flooding and an increase in the amount of surface water stored in the wetland over an annual cycle. Conversely, as the stream channel degrades, available water storage in the channel increases, resulting in less depth, frequency, and duration of flooding and a decrease in the amount of surface water stored in the floodplain wetland over an annual cycle. The duration of water storage is secondarily influenced by the slope and roughness of the floodplain. Slope refers to the gradient of the floodplain across which floodwaters flow. Roughness refers to the resistance to flow created by vegetation, debris, and topographic relief. In general, duration increases as roughness increases and slope decreases.

Description of model variables

Overbank Flood Frequency (V_{FREQ}). This variable is defined as the frequency with which water in an adjacent stream overtops its banks and inundates the riverine wetland (Ainslie et al. 1999). This variable is quantified by determining the recurrence interval in years of overbank flooding. In the context of this function, overbank flood frequency indicates how often peak seasonal discharge inundates a riverine wetland and allows surface water to be temporarily stored (or removes and sequesters elements and compounds, retains particulates, and exports organic carbon, or provides habitat for wildlife) and in many ways, contributes to the overall health of the wetland. Sources of water for riverine wetlands are limited (groundwater, rain, or overbank flooding), and so the frequency at which the water is provided to the wetland is very important. Therefore, the recurrence interval in years is used to quantify this variable. This variable is best derived from streamflow data within the watershed, but these data are not always available. Flood frequency analyses of annual peak flow data, typically by techniques outlined in U.S. Geological Survey (USGS) (1982) using a log-Pearson Type III distribution, provide peak discharges for selected recurrence intervals. Peak discharge data can be used in combination with stream cross-section data at selected sites to determine overbank flooding. Several methods are available for estimating flood frequency recurrence intervals and relating them to overbank flooding:

(1) Determine recurrence interval using one of the following methods (specific guidelines are provided in Appendix C):

- (*a*) Regional flood frequency ratio or regression equations developed by USGS for gaged or ungaged streams (Chow 1959; Bridges 1982; Gillen 1996).
- (*b*) A regional dimensionless rating curve (Ainslie et al. 1999).
- (*c*) Hydrologic models such as HEC-2 (U.S. Army Corps of Engineers 1981, 1982), HEC-RAS (U.S. Army Corps of Engineers 1997), HSPF (Bicknell et al. 1993).
- (*d*) Local knowledge.

(2) Report recurrence interval in years.

In peninsular Florida reference wetlands, using the regional curve or equations for the ratio or regression approach described in Figure C5 produced the recurrence interval ranging from 2 to 100 years (Table D1, (5) V_{FREQ}). Based on the range of values from reference standard sites, a variable subindex of 1.0 is assigned to recurrence intervals less than or equal to 3.0 years (Figure 5). Longer recurrence intervals are assigned a linearly decreasing subindex down to 0.1 at a recurrence interval of 10 years. This is based on the assumption that where entrenchment, channelization, or levees effectively increase the depth of the stream channel, a greater discharge is required to overtop the bank and inundate the riverine wetland. Since greater discharges occur less frequently, the volume of surface water that is temporarily stored in riverine wetlands is less than what characteristically

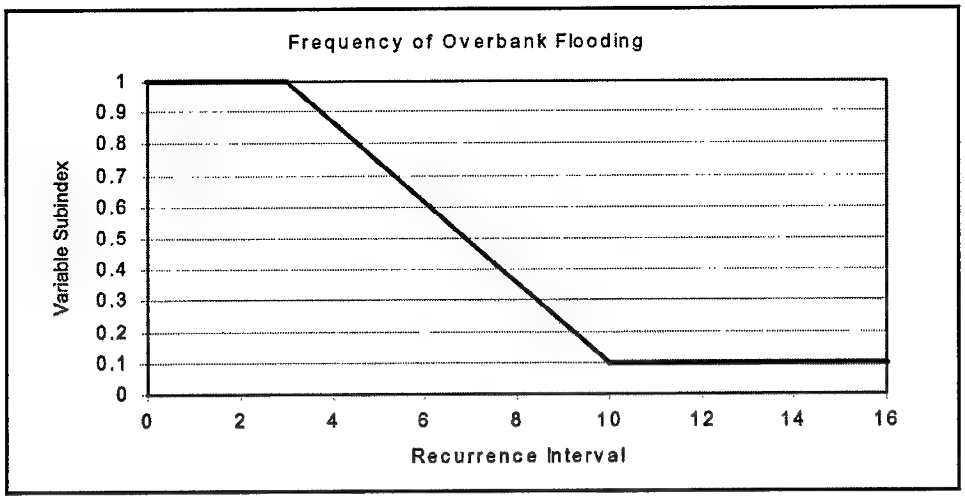

Figure 5. Relationship between frequency of overbank flooding and functional capacity

is stored at reference standard sites in both the short and long term. The rationale for the rate at which the subindex drops to 0.1 (i.e., 1.0 to 0.1) is based on the assumption that as frequency of overbank flow increases, the capacity of the wetland to store annual peak discharges decreases to one-tenth the amount of water stored over a period of 10 years under reference standard conditions. The reasoning for this is that the health of the wetland is greatly influenced by the frequency of overbank flooding, so the greater the frequency of flooding, the greater the impact V_{FREQ} has on the model. Model validation will help to define the actual nature of this relationship. Recurrence intervals greater than 10 years are assigned a subindex of 0.1, based on the assumption that even at longer recurrence intervals, riverine wetlands provide some floodwater storage, albeit infrequently.

Floodplain Storage Volume (V_{STORE}). This variable represents the volume that is available for storing surface water during overbank flood events. In peninsular Florida, the loss of storage volume is usually a result of dikes, roads, levees, or other man-made structures that reduce the effective width of the floodplain. In the context of this function, this variable is designed to detect changes in storage volume that result from these types of structures.

The ratio of floodplain width to channel width is used to quantify this variable. Floodplain width is defined as the distance between the floodplain wetland on opposite sides of the stream measured perpendicular to the channel (Figure 6A). Where artificial structures occur, floodplain width is the distance between the riverside toe of the structure and the floodplain elevation contour (Figure 6B), or the riverside toe of a levee, road or other structure on the opposite side of the stream (Figure 6C). Channel width is defined as the distance between the top of the channel banks measured perpendicular to the flow (Figure 6). The ratio of floodplain width to channel width can be measured using the following method, measuring both sides of the floodplain:

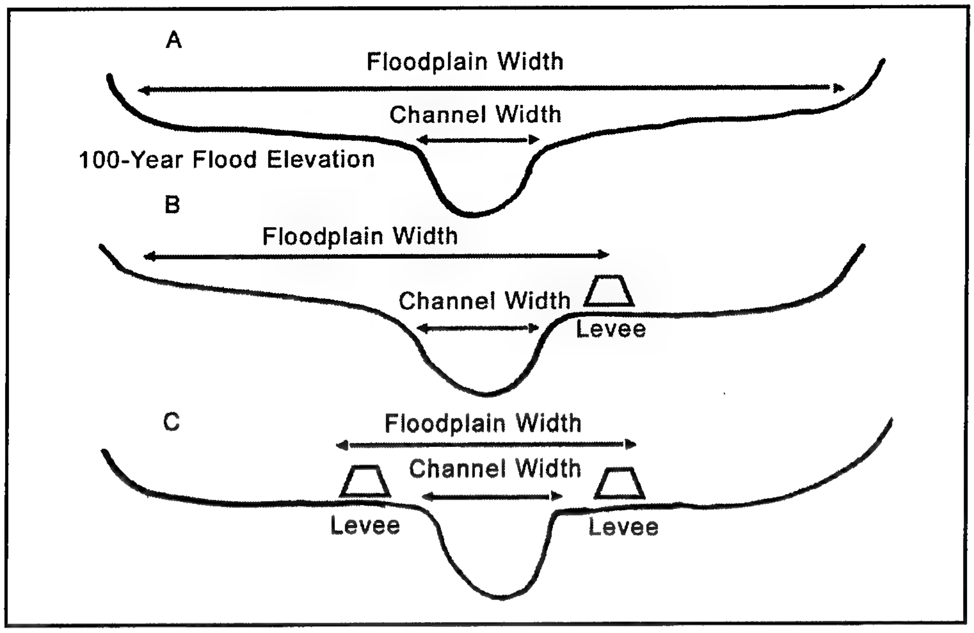

Figure 6. Determining floodplain width and channel width

(1) Measure the width of the floodplain and the width of the channel using surveying equipment or pacing in the field. A crude estimate can be made using topographic maps or aerial photos, remembering that short distances on maps and photographs translate into long distances on the ground (i.e., the width of a section line on a 1:24,000 USGS topographic map represents about 30 ft (9 m) on the ground. The USGS fractional scale of 1:24,000 means that a distance of 1 *unit* on the map represents a distance of 24,000 of the same *units* on the surface of the earth. Therefore, 1 in. (2.5 cm) on the map equals 24,000 in. (60,960 cm) on the earth, or 1 cm on the map equals 24,000 cm on the earth). If USGS topographic maps are used to measure floodplain width, use of the metric scale will provide greater accuracy.

(2) Calculate the ratio by dividing the floodplain width by the channel width.

(3) Report the ratio of floodplain width to channel width as a unitless number.

In peninsular Florida reference wetlands, the ratio of floodplain width to channel width ranged from 0 to 393.42 (Appendix D). Based on the range of values at reference standard wetlands, a variable subindex of 1.0 is assigned to ratios greater than or equal to 30 for this variable (Figure 7). Smaller ratios are assigned a linearly decreasing subindex down to 0 at a ratio of 1. This is based on the assumption that the ratio of floodplain width to channel width is linearly related to the capacity of the riverine wetlands to temporarily store surface water.

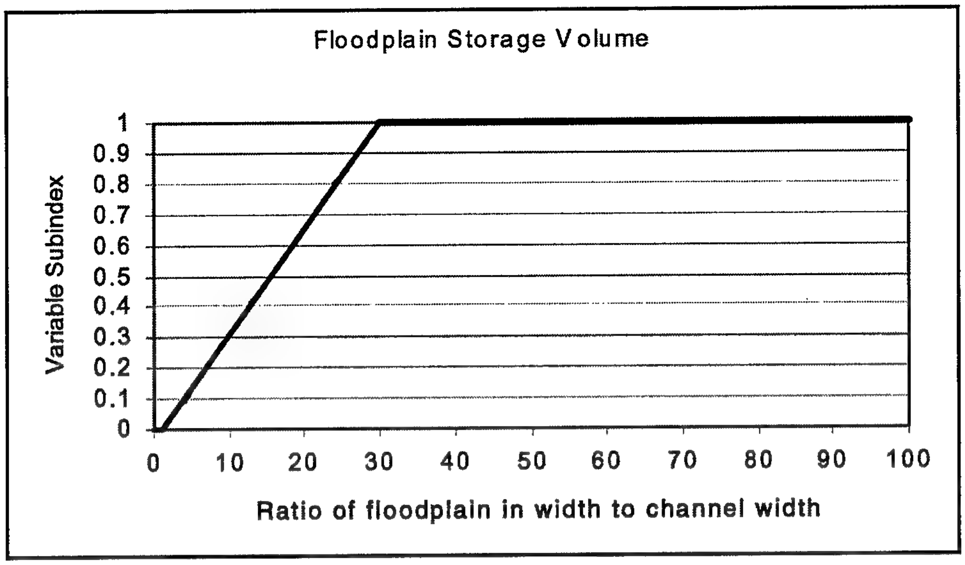

Figure 7. Relationship between floodplain storage volume and functional capacity

Floodplain Slope (V_{SLOPE}). This variable represents various channel and floodplain features in the vicinity of the riverine wetland. The relationship between these features and the temporary storage of surface water is based on the proportional relationship between slope, hydraulic radius, channel roughness, and velocity in Manning's equation (1):

$$V = \frac{\left(1.49 \times R^{2/3}\right)\left(S^{1/2}\right)}{n} \tag{1}$$

where

V = mean velocity of flow, ft/s

R = hydraulic radius, ft, i.e., the cross-sectional area of the channel divided by the wetted perimeter of the channel.

S = slope, ft/ft

n = roughness coefficient

The naturally occurring sequentially spaced riffle/pools and the corresponding coarse/fine bed materials in them are controlled by the morphological features of a river channel. Among these features are the hydraulic radius and the sinuosity of the channel. These features are critical components that contribute to the energy of the flow. Changes in these features can result in a severe increase in downstream energy dissipation and consequential damaging floods with a loss of the temporary storage of surface water in upstream floodplains (Rosgen 1996).

In the context of this function, the variable is likely to change significantly only when any of these channel features or the floodplain has been altered. Floodplain alterations include surface mining, fill, and the placement of

structures in the channel. Channel alterations include channel dredging, straightening, or other streambed modifications (Figure 8).
Impacts or alterations to the channel or floodplain are used to quantify this variable. Measure it with the following procedure:

(1) For floodplain alterations, determine if floodplain alterations such as surface mining, fill, or the placement of structures in the channel have occurred. Assign a value of 0.1.

(2) Channel alterations:

(a) If channel alterations such as channel dredging or straightening or other streambed modifications have occurred, assign a value of 0.

(b) If no alterations have occurred to the floodplain or channel, assign a value of 1.0.

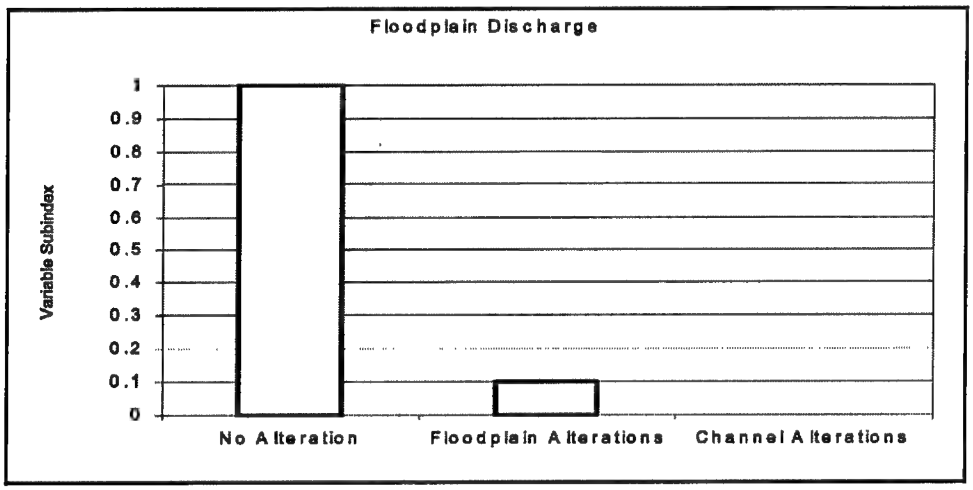

Figure 8. Relationship between floodplain discharge and functional capacity

Floodplain Roughness (V_{ROUGH}). This variable represents the resistance to the flow of surface water resulting from physical structure on the floodplain. The relationship between roughness and the velocity of the surface water flow is expressed by Manning's equation, which indicates that as roughness increases, velocity decreases and storage time increases (Equation 2). Several factors contribute to roughness including the soil surface, surface irregularities (e.g., micro- and macrotopographic relief), obstructions to flow (e.g., stumps and coarse woody debris), and resistance due to vegetation structure (trees, saplings, shrubs, and herbs). Depth of flow is also an important consideration in determining roughness because as water depth increases, obstructions are overtopped and cease to be a source of friction or turbulence causing the roughness coefficient to decrease. Manning's roughness coefficient n is used to quantify this variable. Measure Manning's n at the depth of flooding indicated by onsite data (e.g., stage recorder) or by hydrologic indicators (i.e., silt lines, water marks, bryophyte-lichen lines, debris lines, etc.). If onsite data or indicators are not present, evaluate Manning's n at or slightly above ground surface (i.e., within 1 ft

(0.3 m)). Once the depth of flooding is determined, measure the roughness coefficient n using Arcement and Schneider's (1989) method based on characterization of the different components that contribute to roughness on floodplains. These include micro- and macrotopographic relief (n_{TOPO}), obstruction (n_{OBS}), and vegetation (n_{VEG}). Photographic examples are provided by Arcement and Schneider (1989). The following steps are needed:

(1) Determine n_{BASE}, the contribution to roughness of the soil surface. Arcement and Schneider (1989) suggest using 0.026, the value for firm sandy soil.

(2) Using the descriptions in Table 7, assign adjustment values to the roughness components of n_{TOPO}, n_{OBS}, and n_{VEG}.

(3) Sum the values of the roughness components to determine floodplain roughness. For example, Manning's roughness coefficient $n = n_{BASE} + n_{TOPO} + n_{OBS} + n_{VEG}$.

(4) Report Manning's roughness coefficient as a unitless number.

In peninsular Florida reference wetlands, Manning's roughness coefficient ranged from 0.043 to 0.296 (Appendix D). These values were based on setting n_{BASE} to 0.026, and adjustment values for the topographic relief component (n_{TOPO}), which ranged from 0.0 to 0.02, the obstructions component (n_{OBS}), which ranged from 0.0 to 0.05, and the vegetation component (n_{VEG}), which ranged from 0.005 to 0.2.

Based on the range of values at reference standard sites, a variable subindex of 1.0 is assigned to Manning's roughness coefficients greater than 0.14 (Figure 9). Lower roughness coefficients were assigned a linearly decreasing subindex down to 0.5 at ≤0.03. This reflects the approximate fivefold increase in flow velocity that occurs as floodplain roughness decreases from 0.14 to 0.03 when holding hydraulic radius and slope constant in Manning's equation.

Functional Capacity Index

The assessment model for calculating the FCI for Temporary Storage of Surface Water is as follows:

$$FCI = \left[\left(V_{FREQ} \times V_{STORE} \right)^{1/2} \times \left(\frac{V_{SLOPE} + V_{ROUGH}}{2} \right) \right]^{1/2} \qquad (2)$$

In the model, the capacity of a riverine wetland to temporarily store surface water depends on three characteristics. In the first part of the model, V_{FREQ} indicates the ability of water to get to the riverine wetland as reflected by recurrence interval. The variable V_{STORE} indicates the volume that is available for storing surface water, and reflects whether this volume has been reduced by structures (i.e., levees), fill, or other cultural alterations.

Table 7
Adjustment Values for Roughness Components Contributing to Manning's Roughness Coefficient n

Roughness Component	Adjustment to n Value	Description of Conditions
Topographic Relief (n_{TOPO})	0.0	Representative area is flat with essentially no microtopograhic relief (i.e., hummocks or holes) or macrotopographic relief (i.e., ridges or swales).
	0.005	Microtopographic relief (i.e., hummocks or holes) or macrotopographic relief (i.e., ridges or swales) cover 5-25 percent of a representative area
	0.01	Microtopographic relief (i.e., hummocks or holes) or macrotopographic relief (i.e., ridges or swales) cover 26-50 percent of a representative area.
	0.02	Microtopographic relief (i.e., hummocks or holes) or macrotopographic relief (i.e., ridges or swales) cover >50 percent of a representative area
Obstructions (n_{OBS}) (includes coarse woody debris, stumps, debris deposits, exposed roots)	0.0	Obstructions occupy 1-5 percent of a representative cross-sectional area.
	0.002	Obstructions occupy 6-15 percent of a representative cross-sectional area.
	0.01	Obstructions occupy 16-50 percent of a representative cross-sectional area.
	0.05	Obstructions occupy >50 percent of a representative cross-sectional area.
Vegetation (n_{VEG})	0.0	No vegetation present
	0.015	Representative area covered with herbaceous or shrubby vegetation where depth of flow exceeds height of vegetation by >2-3 times. Vegetation includes ground cover and/or sparse understory cover only.
	0.050	Representative area partially stocked with mature trees and covered with herbaceous or shrubby vegetation where depth of flow is at height of understory vegetation. Vegetation includes ground cover, dense woody undercover with sparse or no tree cover.
	0.1	Representative area fully stocked with mature trees and with sparse herbaceous ground cover and/or sparse woody understory vegetation.
	0.2	Representative area partially to fully stocked with trees and dense herbaceous cover and/or dense woody understory vegetation

Note: Adapted from Arcement and Schneider (1989) and Ainslie et al. (1999).

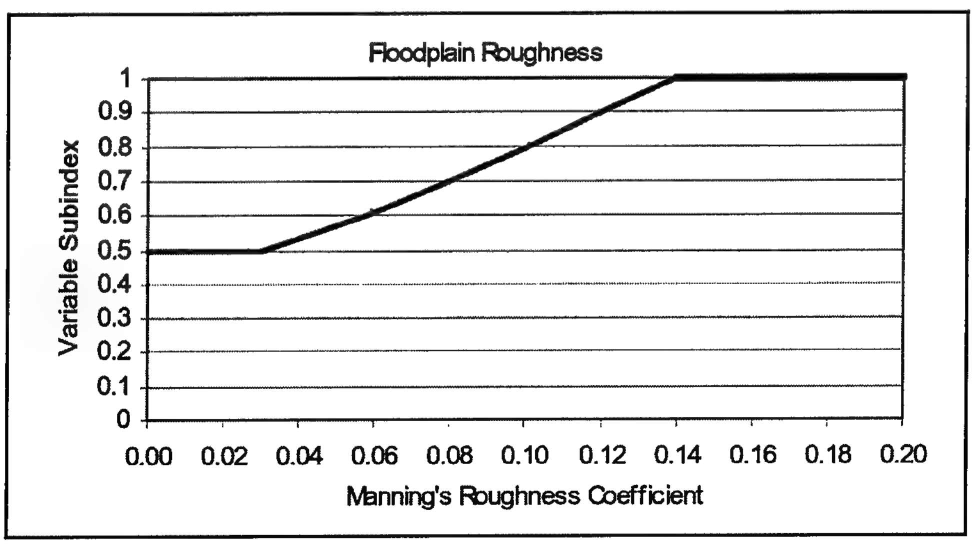

Figure 9. Relationship between floodplain roughness and functional capacity

The relationship between V_{FREQ} and V_{STORE} is assumed to be partially compensatory. This means that the variables contribute independently and equally to the performance of the function (Smith and Wakeley 2001). A geometric mean is used to average the two values. The use of a geometric mean means that if the subindex of a variable drops to 0, the results from that particular portion of the model will be 0. For example, if the subindex for V_{STORE} drops to 0, the results from the first half of the model will be 0. In this particular model, the FCI will also drop to 0 because a geometric mean is used to combine the first and second half of the model. For example, as the recurrence interval decreases, and overbank flow is reduced, or as the width of the floodplain is increasingly constricted by levees or roads, temporary surface water storage is reduced. In the case of a variable subindex dropping to 0, the function is eliminated. Use of an arithmetic mean to combine V_{FREQ} or V_{STORE}, or the first and second part of the equation, would require that the subindices for all variables be 0 in order for the FCI to equal 0, which is clearly inappropriate in this model.

In the second part of the model, V_{ROUGH} and V_{FDC} reflect the ability of the wetland to reduce the velocity of water as it moves through the wetland. These variables are also assumed to be partially compensatory, but in this case they are combined using an arithmetic mean. This makes the model relatively less sensitive to low subindices of V_{ROUGH} and V_{SLOPE} (Smith and Wakeley 2001). This is consistent with the assumption that V_{ROUGH} and V_{FDC} are less important in determining functional capacity than either V_{FREQ} or V_{STORE}.

Function 2: Maintain Characteristic Subsurface Hydrology

Definition

Maintaining Characteristic Subsurface Hydrology is defined as the capacity of a low-gradient, blackwater stream bottomland hardwood forest wetland to transport subsurface water. Potential sources for subsurface water in riverine wetlands are direct precipitation, interflow (i.e., unsaturated subsurface flow), groundwater flow (i.e., saturated subsurface flow), and overbank flooding. A quantitative measurement of this function is the percentage of time during a year that a characteristic or historical average water depth is maintained.

Rationale for selecting the function

This function is integral to the characteristic hydrologic regime of the adjacent stream. Storage and movement of subsurface water contribute to the long-term discharge component of streamflow (base flow) and are particularly significant during periods of low precipitation or when overland

runoff is relatively negligible (Butler 1957; Langbein and Iseri 1960). Subsurface storage/drainage directly affects the size and location of saturated zones near the soil surface and thereby contributes to the rapid response (storm flow) portion of the stream hydrograph during precipitation events (Hewlett and Hibbert 1967; Hewlett and Nutter 1970). Additionally, this function maintains water table depths and soil moisture conditions within the floodplain and directly affects biogeochemical processes and nutrient and material transport.

Characteristics and processes that influence the function

Subsurface water is derived from water that infiltrates the ground surface. Upon infiltration, water may move through the soil as unsaturated (interflow) or within the saturated zone, below the water table, as groundwater. In general, vegetated surfaces in Florida, in combination with sandy soils and relatively flat topography, promote infiltration and discourage stormwater runoff. In Florida, there is the potential for a hardpan or spodic horizon within the soil profile that will impede downward percolation and encourage shallow saturated flow and storage above the hardpan. In general, subsurface water will flow laterally according to differences in hydraulic head between higher elevations within the floodplain and the channel banks of the stream. This hydraulic gradient will typically mirror the gentle topographic gradient and will produce a subsurface flow several orders of magnitude less than the streamflow or surface runoff rates. The rate of subsurface flow will also be affected by soil and sediment characteristics such as permeability and porosity. Subsurface flow will generally flow more quickly through sand than clay. Although Florida's soils are typically sandy, organic clay layers may be found within the floodplain that can alter flow direction and rates. Precipitation characteristics, such as duration and intensity, will also influence water table depths, hydraulic gradients, and rates of subsurface flow.

The relationship between the rate of subsurface water flow through a porous material, hydraulic gradient, and permeability is described by Darcy's law and is generally stated (Fetter 1980) as:

$$Q = -K_{sat} A\left(\frac{dh}{dl}\right) \tag{3}$$

where

Q = discharge, volume/time

K_{sat} = saturated hydraulic conductivity, length/time

A = area through which water is flowing, length^2

dh/dl = hydraulic gradient or change in hydraulic head, length/length

The negative sign indicates that flow is in the direction of decreasing hydraulic head.

Saturated hydraulic conductivity is determined by the characteristics of the soil and the nature of the fluid moving through the soil (Fetter 1980; Heath and Conover 1981). However, since the only fluid of interest here is water, properties of the fluid such as specific weight and dynamic viscosity can be considered constant. This leaves the characteristics of the soil as the only factors of concern in determining saturated hydraulic conductivity (Watson and Burnett 1993). Modern county soil surveys provide information on the permeability of soils, which is equivalent to saturated hydraulic conductivity (U.S. Department of Agriculture (USDA) NRCS 1996).

The area factor A in Darcy's general equation, like the properties of the fluid, can be considered constant for the purposes of rapidly assessing subsurface hydrology. The final factor in Darcy's general equation, hydraulic gradient, can be thought of as the force that moves water through the soil. Increasing the hydraulic gradient will increase discharge in the same type of soil. However, soils with different hydraulic conductivities that are subjected to the same hydraulic gradient will transmit water at different rates. For example, water will move through a sandy soil faster than through a clay soil under the same hydraulic gradient because the sandy soil has a higher hydraulic conductivity. In the context of rapid assessment the slope of the water table from uplands to the stream channel represents the hydraulic gradient in Darcy's general equation.

There are several activities that have the potential to affect hydraulic gradients and/or hydraulic conductivities in bottomland hardwood forests. Ditching or pumping for agricultural or phosphate mining purposes can alter drainage rates and hydraulic gradients. Heavy equipment associated with these activities can compact soils and affect soil permeabilities and infiltration rates. Water resource management practices such as channelization, impoundments, along with rapid urbanization can also affect subsurface drainage patterns. Many of these activities have been documented for bottomland hardwood floodplains within the Southwest Florida Water Management District (Estevez, Dixon, and Flannery 1991; Livingston 1991).

Description of model variables

Subsurface Water Velocity ($V_{SOILPERM}$). This variable represents the rate at which water moves down the hydraulic gradient through riverine wetland soils and into the stream channel. This variable can be estimated by using soil permeability, which for this purpose is equivalent to saturated hydraulic conductivity. Relatively higher permeabilities typically suggest relatively more rapid movement of subsurface flow whereas relatively lower permeabilities indicate slower rates of water movement.

Soil permeability is used to quantify this variable. Measure it with the following procedure:

(1) If the soils have not been altered, use the following alternatives:

(*a*) An alternative method is to assign a value to soil permeability by calculating the weighted average of median soil permeability to a depth of 20 in. (0.5 m). Values for soil permeability can be obtained from county soil surveys. Permeabilities and weighted average permeabilites for soil series associated with bottomland hardwood forests in the reference domain (sixteen counties within the Southwest Florida Water Management District) are tabulated in Table 8.

(*b*) The following example demonstrates how each weighted average permeability was determined. The Bradenton series has a median soil permeability of 13 in./hr (0.3 m/hr) for 0- to 13-in. (0.3 m) depth, and a median soil permeability value of 1.3 in./hr (33 mm/hr) from 13- to 20-in. (0.3- to 0.5-m) depth. The weighted average of the median soil permeability for the top 20 in. (0.5 m) is

$$[(13 \times 13) + (7 \times 1.3)]/20 = 9 \tag{4}$$

(2) If soils in the area being assessed have been altered by agricultural activity, silvicultural activity, placement of fill, use of heavy equipment in construction projects or surface mining, or any other activities with the potential to alter effective soil permeability.

(3) If soils have been altered select one of the following; otherwise use Step 1.

(*a*) Assign a value to soil permeability based on a representative number of field measurements of soil permeability. The number of measurements will depend on how variable and spatially heterogenous the effects of the alterations are on soil properties.

(*b*) Assign a variable subindex based on the category of alteration that has occurred at the site (Table 9). (Note: in this particular situation no value is assigned to soil permeability; rather a variable subindex is assigned directly).

Soil permeability is generally measured in inches/hour. For the purpose of rapid assessment, report saturated hydraulic conductivity as alteration of soil in depth or unaltered soils.

In the reference domain within peninsular Florida, soil permeability ranges from less than 0.06 in./hr (1.5 mm/hr) to greater than 20 in./hr (0.5 m/hr) (County Soil Surveys). A variable subindex of 1.0 was assigned to unaltered sites with a soil permeability of less than or equal to 6 in./hr (0.15 m/hr) (Figure 10). As soil permeability increases, a decreasing subindex is assigned based upon the assumption that the increase in permeability is linearly related to the ability of the wetland to maintain its characteristic

Table 8
Permeability/Saturated Hydraulic Conductivity by Soil Layer (Upper 20 in. (0.5 m)) for Hydric Soil Series Associated with Bottomland Hardwood Forests in Peninsular Florida

Soil Series	Depth, in.	Range of Soil Permeability in./hr	Weighted Average Soil Permeability for Upper 20 In. (0.5 m), in./hr
Anclote	0-20	6.0-20	13
Astor	0-20	6.0-20	13
Basinger	0-20	6.0-20	13
Bluff	0-13; >13-20	0.2-0.6; 0.06-0.2	0.3
Bradenton	0-13; >13-20	6.0-20; 0.6-2.0	9
Chobee	0-15; >15-20	2.0-6.0; <0.2	3
Delray	0-20	6.0-20	13
Felda	0-20	6.0-20	13
Floridana	0-20	6.0-20	13
Holopaw	0-20	6.0-20	13
Iberia	0-20	<0.06	<0.1
Malabar	0-20	6.0-20	13
Manatee	0-10; >10-20	2.0-6.3; 0.63-2.0	3
Nittaw	0-6; >6-20	0.6-6.0; 0.06-0.2	1
Pineda	0-20	6.0-20	13
Placid	0-20	6.0-20	13
Pompano	0-20	>20	>20
Wabasso	0–20	6.0-20	13
Winder	0–14; >14–17; >17–20	6.0-20; 0.2-0.6; <0.2	9

Note: To convert inches to meters, multiply by 0.0254.

Table 9
Soil Permeability Values, in./hr, for Silvicultural, Agricultural, Mining, and Other Soil Alterations

Alteration Category	"Typical" Soil Permeability after Alteration	Average Depth of Alteration Effects	Variable Subindex
Activities that compact surface layers and reduce permeability to a depth of about 6 in. (0.15 m) (Aust 1994), such as with silviculture.	Highly variable and spatially heterogeneous	Top 6 in. (0.15 m) of soil profile	0.5
Activities such as agricultural tillage or pavers, etc., that create some surface compaction as well as generally decreasing the average size of pore spaces. These activities decrease the ability of water to move through the soil to a depth of about 6 in. (0.15 m) (Drees et al. 1994).	Highly variable and spatially heterogeneous	Top 6 in. (0.15 m) of soil profile	0.5
Compaction resulting from large equipment over the soil surface, cover of soil surface with pavement or fill material, or excavation and subsequent replacement of heterogeneous materials such as with construction activities/surface mining.	Highly variable and spatially heterogeneous	Entire soil profile	0.1

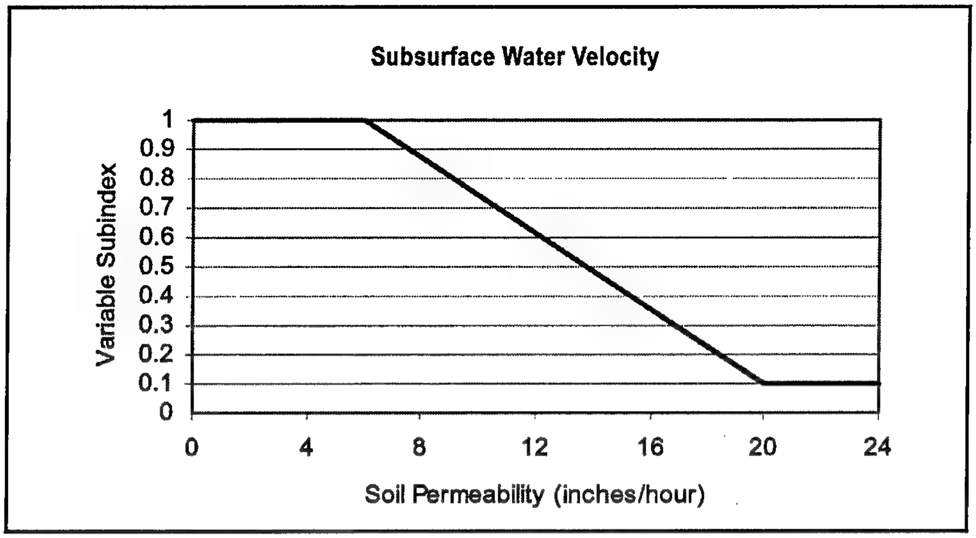

Figure 10. Relationship between saturated hydraulic conductivity and functional capacity (to convert soil permeability to meters per hour, multiply by 0.0254)

subsurface hydrology. A soil permeability equal to or greater than 20 in./hr (0.5 m/hr) is assigned a subindex of 0.1 based on the assumption that all soils generate a resistance to the flow of subsurface water. Soils altered or impacted by agricultural activities (e.g., plowing or cultivation) or silvicultural activities (e.g., cutting, shearing, or skidding) were assigned a variable subindex of 0.5. This is based on data from Aust (1994) and Drees et al. (1994), which indicate that as a result of these activities soil properties are generally altered in the upper 6 in. (0.15 m) of the soil profile. This means that soil permeability in the lower 14 in. (0.4 m), or 70 percent, of the 20-in. (0.5-m) soil profile is unaltered. Thus, a subindex of 0.5 is assigned. Sites altered by construction activities, surface mining, or other activities that affect the entire soil profile are assigned a subindex of 0.1 based on the fact that all soils, regardless of their permeability, reduce the velocity of water to some degree as it moves through the soil. It is assumed that the vertical and lateral characteristics of this variable will be affected by these activities through changes in soil structure and infiltration rates. It is difficult to predict the direction of change that some of these activities might induce with respect to permeability. For the purposes of rapid assessment, it is assumed that lateral flow will be increased, while vertical movement will be decreased, thereby increasing movement of water down-gradient into the stream channel. As previously stated, a subindex of 0.1 is assigned assuming that all soils will generate some resistance to subsurface flow.

Water Table Slope ($V_{WTSLOPE}$). This variable represents the change in elevation of the water table moving from upland areas adjacent to the riverine wetland to the nearest stream channel along a line perpendicular to the center line of the floodplain within the bottomland hardwood forest. It is considered to be the hydraulic gradient for subsurface water flow. Generally, in undisturbed floodplains, the water table mirrors the topographic surface. In most cases within the reference domain, the water table would be

expected to be relatively flat or gently sloping towards the stream channel within the floodplain. Impacts or changes in slope can result from wells, ditching, or other activities that might influence subsurface water movement. If there are no obvious effects due to agriculture, etc., on the hydraulic gradient within the floodplain, a subindex of 1.0 is assigned. If channelization or other effects have occurred within the floodplain, then a value of 0.1 is assigned. It is difficult to determine the direction or magnitude of change in hydraulic gradient that a particular activity might cause. For the purpose of rapid assessment, a value of 0.1 is intended to characterize an increase in water table slope or hydraulic gradient and therefore increase the rate of subsurface flow (Figure 11).

Functional Capacity Index

The model for deriving the FCI for Maintaining Characteristic Subsurface Hydrology is as follows:

$$FCI = (V_{SOILPERM} \times V_{WTSLOPE})^{1/2} \qquad (5)$$

The FCI is essentially a representation of Darcy's law. The two variables $V_{SOILPERM}$ and $V_{WTSLOPE}$ represent the variables K_{sat} (hydraulic conductivity) and *dh/dl* (hydraulic gradient), respectively, in Darcy's equation. These values represent the movement of subsurface water at a rate determined by the slope of the water table and soil permeability. The variables are multiplied together and geometrically averaged in order to represent the partially compensatory relationship between hydraulic conductivity and water table slope (Smith and Wakeley 2001).

Function 3: Cycle Nutrients

Definition

Cycling nutrients is defined as the ability of a low-gradient, blackwater stream bottomland hardwood forest to receive nutrient inputs, store nutrients in biotic and abiotic pools, circulate and transform nutrients through living and dead organic matter, replenish nutrients through decomposition and weathering, and remove nutrients through leaching, gaseous, and other losses. In this biogeochemical approach, specific nutrients are not considered individually. Instead, all nutrients in general are considered by this function, which is quantified as the amount of nutrients processed per unit area, g/m^2, over a period of one year or less.

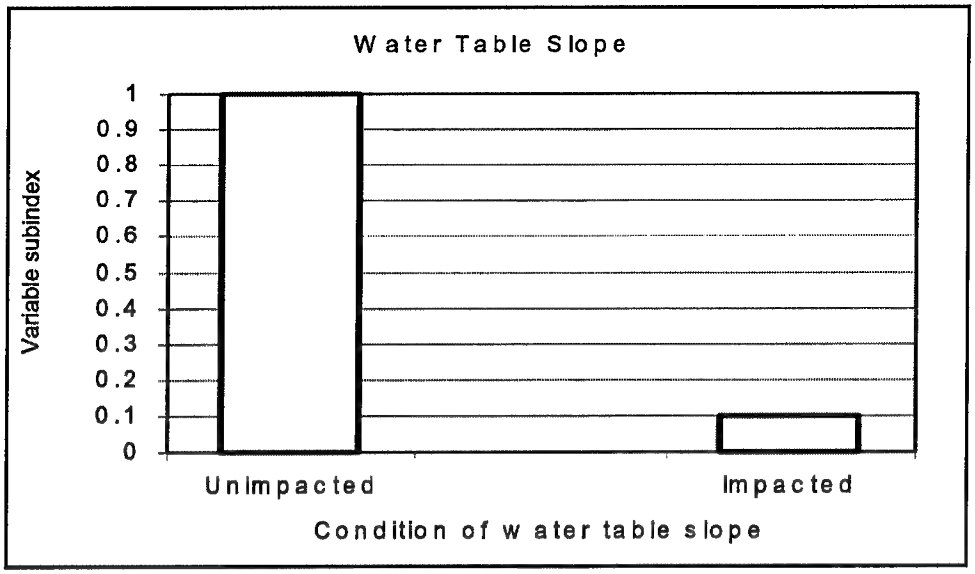

Figure 11. Relationship between water table slope and functional capacity

Rationale for selecting the function

Nutrient cycling is an important function because without cycling of nutrients, wetland ecosystems would quickly become depleted of nutrients. The loss of nutrients in the system would result in decreased primary and secondary production as well as reduced rates of decomposition. For example, an adequate supply of nutrients in the soil profile supports primary production, which makes it possible for the plant community to develop and be maintained (Bormann and Likens 1970; Whittaker 1975; Perry 1994). The plant community in turn provides a pool of nutrients and source of energy for secondary production, and provides the habitat structure necessary to maintain the animal community (Fredrickson 1978; Crow and MacDonald 1978; Wharton et al. 1981). Plant and animal communities serve as the source of detritus, which provides nutrients and energy necessary to maintain a characteristic community of decomposers to break down organic material into simpler elements and compounds that can then reenter the nutrient cycle (Reiners 1972; Dickinson and Pugh 1974; Pugh and Dickenson 1974; Schlesinger 1977; Singh and Gupta 1977; Hayes 1979; Harmon, Franklin, and Swanson 1986; Vogt, Grier, and Vogt 1986).

Characteristics and processes that influence the function

Nutrient cycling is a fundamental process in wetland ecosystems mediated to a large degree by hydrology and by the growth and decomposition of vegetation. In general, sites with higher levels of nutrients have higher levels of net primary production (Mitsch and Gosselink 1993). As plants grow, they take up nutrients that are stored for relatively long periods in belowground rhizomes and woody tissue, or for shorter periods in herbaceous or deciduous plant parts. Nutrients stored in plants are released when plants

senesce, die, and decompose, as well as through leaching and grazing (Schlesinger 1991).

Plant primary production and decomposition are two processes that have been studied relatively intensively (Brinson, Lugo, and Brown 1981). Aerial primary productivity (annual turnover of leaves and fine woody debris) and biomass accumulation in mature and successional stages of forested wetlands have been documented (Brinson 1990). However, larger woody debris and belowground productivity have received less attention.

Nutrient cycling can be assessed directly and quantitatively by measuring the rate at which plant biomass accumulates, turns over (annual litter fall), and decomposes, and by analyzing the concentration of nutrients associated with each phase. The time and level of effort required to accomplish this are typically well beyond the resources available. Consequently, this function must be assessed indirectly using variables or indicators that reflect nutrient cycling in the wetland. One assumption is that the presence of living biomass indicates that nutrient uptake is occurring. Stand age, leaf area index, basal area, and biomass have all been used as proxy measures of primary production in developing forest stands (Mengel and Lea 1990). Therefore, a measure of standing stocks of trees, density or cover of shrubs, and other forms of plant cover can be used to estimate primary production.

Similarly, decomposition is presumed if fallen and dead organic debris exist on the forest floor in the form of leaf litter and humus (O horizon). Most of the annual nutrient cycling occurs at the surface and close to the surface in the O and A soil horizons and coarse woody debris.

Description of model variables

Tree Biomass (V_{TBA}). This variable represents the total mass of organic material per unit area in trees that occupy the stratum in riverine forests. Trees are defined as woody stems ≥6 m in height and ≥10 cm diameter at breast height (dbh). Diameter is by convention measured at 1.3 m above ground level and can be easily converted to basal area, which is closely related to stand development and maturity (Brower and Zar 1984), and represents the simplest form of forest stand characterization. Basal area is the area occupied by the tree stems and represents the mass of organic material per unit area in the tree stratum. In the context of this function, basal area serves as an indication that trees are present, taking up nutrients, and producing biomass.

Tree basal area, a common measure of abundance and dominance in forest ecology that has been shown to be proportional to tree biomass (Whittaker 1975; Whittaker et al. 1974; Spurr and Barnes 1981; Tritton and Hornbeck 1982; Bonham 1989), is used to quantify this variable. Measure it with the following procedure:

(1) Identify the species and measure the dbh in cm of all trees in a circular, 11.3-m-radius sampling unit (Pielou 1984) or 20 m on each side for a square plot (Mueller-Dombois and Ellenberg 1974; Braun-Blanquet 1951) hereafter called a plot (0.04-ha sampling unit).

(2) Convert each of the diameter measurements to area, sum them, and convert to square meters. For example, if three trees with diameters of 20 cm, 35 cm, and 22 cm were present in the plot, the conversion to square meters would be as follows: remembering that the diameter of a circle D can be converted to area A using the relationship $A = \frac{1}{4}\pi D^2$, it follows that $\frac{1}{4}\pi 20^2 = 314$ cm^2, $\frac{1}{4}\pi 35^2 = 962$ cm^2, $\frac{1}{4}\pi 22^2 = 380$ cm^2. Summing these values gives 314 + 962 + 380 = 1656 cm^2 and converting to square meters by multiplying by 0.0001 gives 1656 cm^2 × 0.0001 = 0.17 m^2.

(3) If multiple 0.04-ha plots are sampled, average the results from all plots.

(4) Convert the results to a per-hectare basis by multiplying by 25, since there are 25 0.04-ha plots in a hectare. For example, if the average value from all the sampled plots is 0.17 m^2, then 0.17 m^2 × 25 = 4.3 m^2 ha^{-1}.

(5) Report tree basal area in m^2 ha^{-1}.

Tree basal area in reference standard wetlands ranged from 31 to 73 m^2/ha with an average dbh of 38 cm. When basal area is >30 m^2/ha, a subindex of 1.0 is assigned (Figure 12). This situation is represented by the relatively rare wetland sites with mature forests. Riverine wetlands with forests in the early successional or midsuccessional stages are common in peninsular Florida due to past logging activity. In these situations basal area is lower and the subindex decreases linearly to zero at zero to reflect the deflection from the reference standard condition. This is based on the assumption that the relationship between tree basal area and the capacity of the riverine

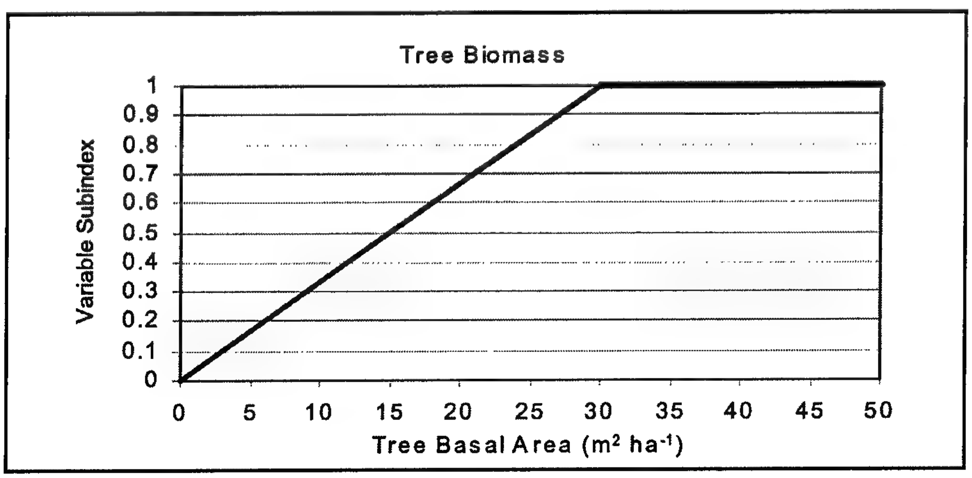

Figure 12. Relationship between tree biomass and functional capacity

wetland to cycle nutrients is linear. Basal area in riverine wetlands cleared for phosphate mining, commercial or residential development, or the production of agricultural crops or grazing ranged from 0.0 to 19 m^2/ha.

Understory Vegetation Biomass (V_{SSD}). This variable represents the total mass of organic material per unit area in the understory stratum of riverine forests. Understory vegetation is defined as woody stems (e.g., shrubs, saplings, and understory trees) >1 m in height and <10 cm dbh. In the context of this function, this variable serves as an indication that understory vegetation is present, taking up nutrients, and producing biomass. Stem density (stems/hectare) is used to quantify this variable. Measure it with the following procedure:

(1) Identify the species and count the stems of understory vegetation in two 0.004-ha sampling units (hereafter called subplots) located in representative portions from two quadrants of each 0.04-ha plot. Sample using one 0.004-ha subplot for each 0.04-ha plot if the stand is in an early stage of succession and a high density of stems makes additional sampling impractical.

(2) If 0.004-ha subplots are used, average the results and multiply by 10 to serve as the value for each 0.04-ha plot.

(3) If multiple 0.04-ha plots are sampled, average the results from all 0.04-ha plots.

(4) Convert the results to a per-hectare basis by multiplying by 25. For example, if the average of 0.04-ha plots is 23 stems, then 23 × 25 = 575 stems/ha.

(5) Report understory vegetation biomass as density of stems/ha.

The number of 0.04-ha plots required to adequately characterize the area being assessed will depend on its size and heterogeneity. The chapter "Assessment Protocol" provides guidance for determining the number and layout of sample points and sampling units.

In west-central peninsular Florida reference wetlands, understory vegetation stem density ranged from 0 to nearly 2,500 stems/ha (Appendix D). Based on data from reference standard sites, a variable subindex of 1.0 is assigned when understory vegetation stem density is between 150 and 1,700 stems/ha (Figure 13). As understory stem density decreases, a subindex linearly decreasing to zero at zero stems/ha is assigned. This is based on the assumption that if understory vegetation does not exist, it does not contribute to nutrient cycling. As understory vegetation stem density increases above 1,400 stems/ha, a linearly decreasing subindex is assigned down to 0.5 at 1,900 stems/ha. Above 1,900 stems/ha a subindex of 0.5 is assigned. The rationale for this is that it is common for understory stem density to exceed 500 stems/ha during the middle stages of succession (Whittaker 1975). As the forest matures, competition for resources results in a decrease in understory stem density to the levels observed at reference standard sites. The rate at which the subindex increases, decreases, and levels

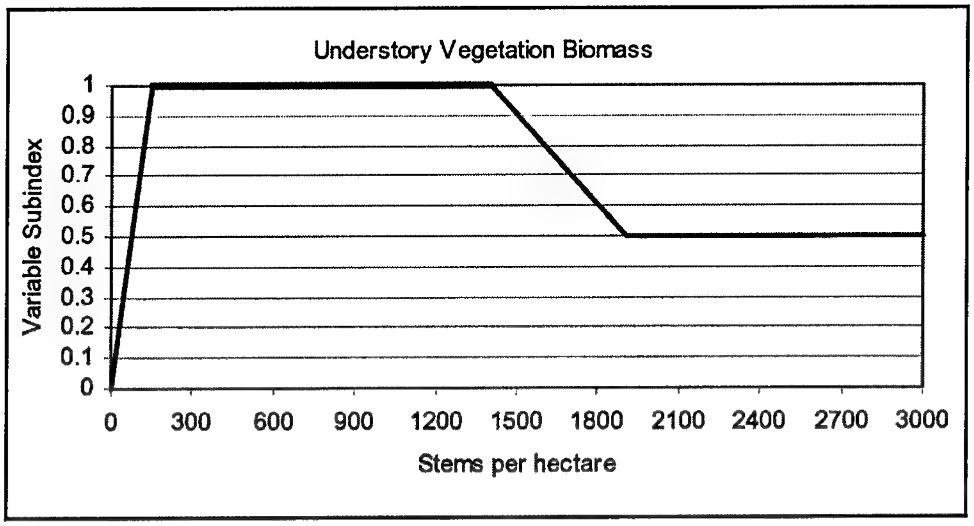

Figure 13. Relationship between understory vegetation biomass and functional capacity

out above 1,400 stems/ha represents an educated guess of the relationship between understory stem densities and nutrient cycling. These assumptions could be validated using the data from a variety of low-gradient riverine wetlands in the southeast summarized by Brinson (1990), Christensen (1991), Sharitz and Mitsch (1993) and Messina and Conner (1997), or by the independent, quantitative measures of function identified previously.

Ground Vegetation Cover (V_{GVC}). This variable represents the total mass of organic matter in the woody and herbaceous vegetation near the surface of the ground in riverine forests. Ground vegetation is defined as all herbaceous and woody vegetation <1 m in height. In the context of this function, this variable serves as an indicator that ground vegetation is present, taking up nutrients and producing biomass. Percent cover of ground vegetation is used to quantify this variable.

There are two alternatives for measuring percent ground vegetation biomass:

(1) Alternative one.

(*a*) Visually estimate the percentage of ground surface that is covered by ground vegetation in the Wetland Assessment Area (WAA) by mentally projecting the leaves and stems of ground vegetation to the ground surface. Walking through the WAA and viewing the ground cover vegetation from above is suggested as this provides a more accurate and precise measure of cover due to vegetation stratification and multiple layering.

(*b*) Report ground vegetation cover as a percent.

(2) Alternative two.

(*a*) Visually estimate the percentage of the ground surface that is covered by ground vegetation by mentally projecting the

leaves and stems of ground vegetation to the ground surface in each of the six m^2 sampling units, hereafter called subplots, placed in representative portions of each quadrant of a 0.04-ha plot. The number of 0.04-ha plots required to adequately characterize an area will depend on its size and heterogeneity. The chapter "Assessment Protocol" provides guidance for determining the number and layout of sample points and sampling units.

(*b*) Average the values from the six m^2 subplots.

(*c*) If multiple 0.04-ha plots are sampled, average the results from all the 0.04-ha plots.

(*d*) Report ground vegetation cover as a percent.

In west-central peninsular Florida reference wetlands, ground cover ranged from 16 to 100 percent cover (Appendix D). In reference standard wetlands, the amount of ground vegetation is relatively small due to the low level of light that occurs near the ground surface as a result of light interception by trees, saplings, and shrubs. Based on data from reference standard sites, a variable subindex of 1.0 is assigned to sites with a ground vegetation cover between 0 and 50 percent (Figure 14). As ground vegetation cover increases to greater than 50 percent, a linearly decreasing subindex down to 0.1 at 100 percent ground cover vegetation is assigned. This is based on the assumption that even when the ground cover vegetation is high, some overstory and understory vegetation will probably be present and contribute to nutrient cycling. Also, an increase in ground vegetation cover indicates a higher level of light at the ground surface and fewer trees, saplings, and shrubs to maintain a characteristic level of nutrient cycling. These assumptions could be validated using the independent, quantitative measures of function defined previously.

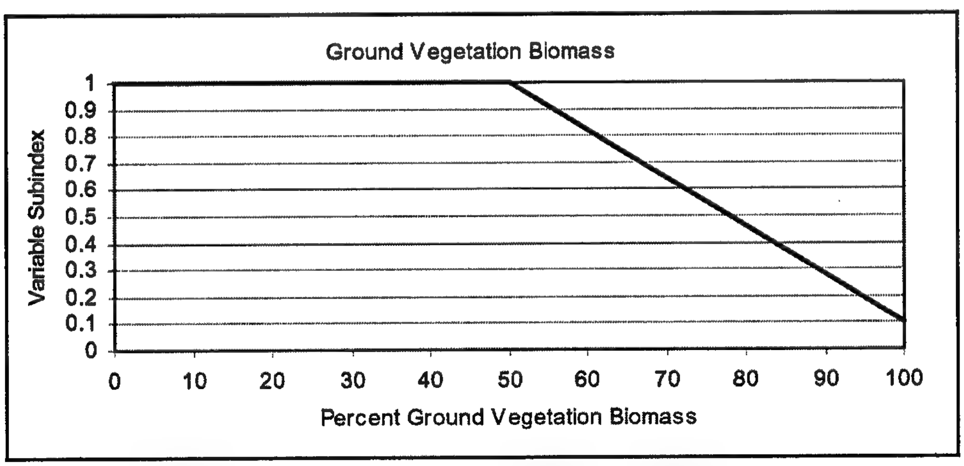

Figure 14. Relationship between ground vegetation biomass and functional capacity

O Horizon Biomass (V_{OHOR}). This variable represents the total mass of organic matter in the O horizon. The O horizon is defined as the soil

layer dominated by organic material that consists of recognizable or partially to highly decomposed organic matter such as leaves, needles, sticks or twigs <0.6 cm in diameter, flowers, fruits, insect frass, moss, or lichens on or near the surface of the ground (USDA Soil Conservation Service (SCS) 1993). The O horizon is synonymous with the terms detritus or litter layer used by other disciplines. In the context of this function, this variable serves as an indicator that nutrients in vegetative organic matter are being recycled.

Percent cover of the O soil horizon is used to quantify this variable. The procedure for measuring it is as follows:

(1) Visually estimate the percentage of the ground surface that is covered by an O horizon in each of four 1-m^2 subplots placed in representative portions of each quadrant of a 0.04-ha plot. The number of 0.04-ha plots required to adequately characterize the area being assessed will depend on its size and heterogeneity. The chapter "Assessment Protocol" provides guidance for determining the number and layout of sampling points and sampling units.

(2) Average the results from the 1-m^2 subplots within each 0.04-ha plot.

(3) If multiple 0.04-ha plots were sampled, average the results from these plots.

(4) Report O horizon cover as a percent.

In west-central peninsular Florida reference wetlands, percent O horizon measured 100 percent (Appendix D). Based on data from reference standard sites, a variable subindex of 1.0 is assigned when the O soil horizon is 100 percent (Figure 15). As O horizon cover decreases, a subindex linearly decreasing to zero at zero percent cover is assigned. The rate at which the subindex decreases, and the selection of 0 as the subindex at 0 percent cover are based on the assumption that the relationship between O soil horizon cover and organic carbon export is linear, and that a decreasing amount of biomass in the tree, sapling, shrub, and ground vegetation strata of the plant community is reflected in lower percent O soil horizon cover. When percent O soil horizon declines to zero, sequestration by organic matter has essentially ceased. These assumptions could be validated using the independent, quantitative measures of function defined previously.

A Horizon Biomass (V_{AHOR}). This variable represents total mass of organic matter in the A horizon. The A horizon is defined as a mineral soil horizon that occurs at the ground surface, or below the O soil horizon, and consists of an accumulation of unrecognizable decomposed organic matter mixed with mineral soil (USDA SCS 1993). In addition, for the purposes of this procedure, in order for a soil horizon to be considered an A horizon it must be at least 7.5 cm (3 in.) thick, and have a Munsell color value less than or equal to 4. In the context of this function, this variable serves as an indicator that nutrients in vegetative organic matter are being recycled.

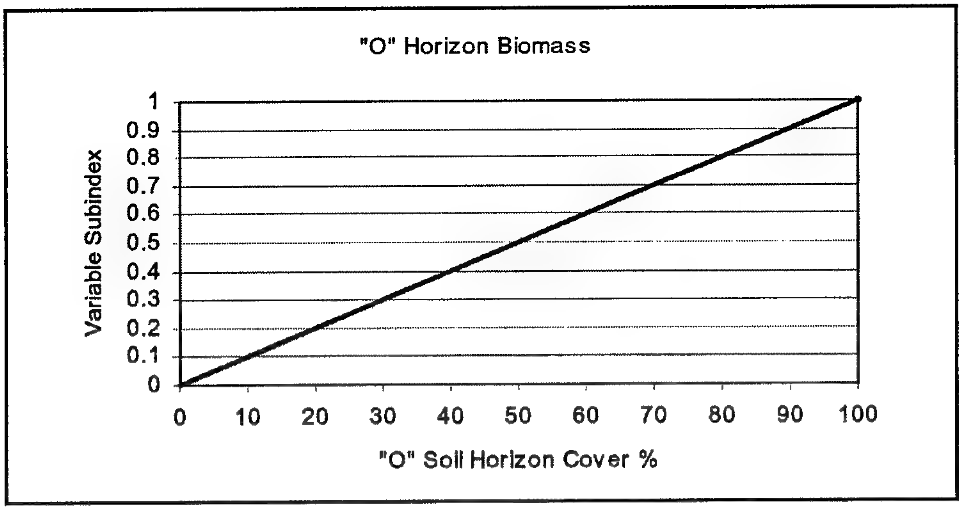

Figure 15. Relationship between O horizon biomass and functional capacity

Percent cover of the A soil horizon is used to quantify this variable. Measure it with the following procedure:

(1) Estimate the percentage of the mineral soil within the top 15 cm (6 in.) of the ground surface that qualifies as an A horizon by making a number of soil observations in each of four 1-m^2 subplots placed in representative portions of each quadrant of a 0.04-ha plot. For instance, if in each subplot 12 soil plugs are taken and 6 show the presence of a 7.5-cm- (3-in.-) thick A horizon, the value of the A horizon cover is $(6/12) \times 100 = 50$ percent. The number of 0.04-ha plots required to adequately characterize the area being assessed will depend on its size and heterogeneity. The chapter "Assessment Protocol" provides guidance for determining the number and layout of sampling points and sampling units.

(2) Average the results from the 1-m^2 subplots within each 0.04-ha plot.

(3) If multiple 0.04-ha plots were sampled, average the results from these plots.

(4) Report A horizon cover as a percent.

In west-central peninsular Florida reference wetlands, A horizon cover ranged from 0 to 100 percent (Appendix D). Based on data from reference standard sites, a variable subindex of 1.0 is assigned when the percent cover of the A horizon is 100 percent (Figure 16). As the percent cover of the A horizon decreases, a subindex linearly decreasing to zero at zero percent cover is assigned. This is based on the assumption that the relationship between percent A horizon and the capacity to cycle nutrients is linear and reflects decreasing contribution to A horizon biomass by the tree, sapling, shrub, and ground vegetation strata of the plant community. Sites that have been converted to agricultural crops may have low coverage of the A horizon due to the oxidation of the organic carbon following tillage (Ismail, Blevins, and Frye 1994).

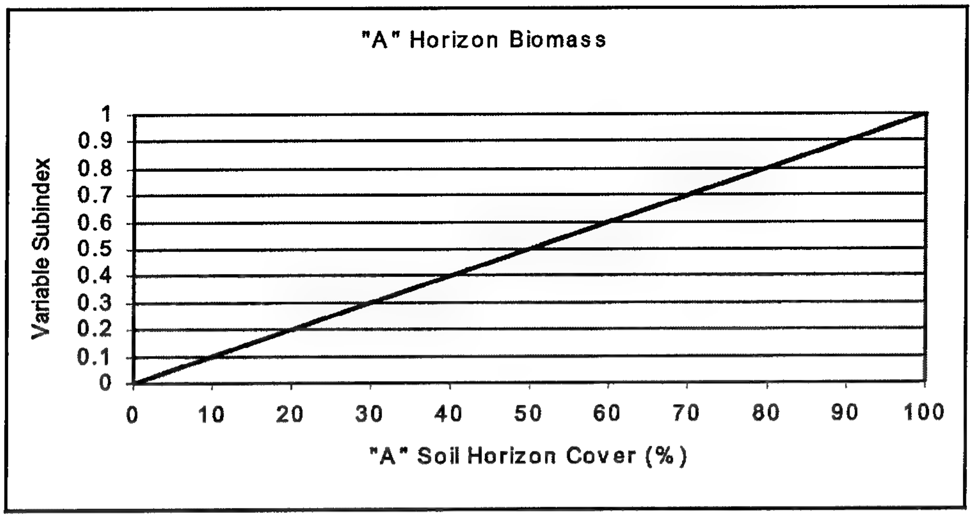

Figure 16. Relationship between A horizon biomass and functional capacity

Woody Debris Biomass (V_{WD}). This variable represents the total mass of organic matter contained in woody debris on or near the surface of the ground. Woody debris is defined as down and dead woody stems ≥0.25 in. (6 mm) in diameter that are no longer attached to living plants. Despite its relatively slow turnover rate, woody debris is an important component of food webs and nutrient cycles of temperate terrestrial forests (Harmon, Franklin and Swanson 1986), and in the context of this function accounts for the contribution woody debris makes to exported organic carbon.

Volume of woody debris per hectare is used to quantify this variable. Measure it with the following procedure adapted from Brown (1974) and Brown, Oberheu, and Johnston (1982):

(1) Count the number of stems that intersect a vertical plane along a minimum of two 50-ft (15-m) transects located randomly, and at least partially inside each 0.04-ha plot.

(2) Count the number of stems that intersect the vertical in two size classes (0.25 to ≤1.0 in. (6 to ≤25 mm) and >1.0 to ≤3.0 in. (>25 to ≤76 mm)) along the transect distance.

(3) In addition to counting the stems, measure the diameter for all stems in the >3-in.- (76-mm-) diam class.

(4) Convert stem counts for each size class to tons per acre using the following formulas:

$$\text{tons/acre} = \frac{\left(11.64 \times n \times d^2 \times s \times a \times C\right)}{N \times l} \tag{6}$$

where

n = total number of intersections (i.e., counts) on all transects

d^2 = squared average diameter for each size class

s = specific gravity (Birdsey (1992) suggests a value of 0.58)

a = nonhorizontal angle correction (suggested value 1.13)

C = slope correction factor (suggested value 1.0 since slopes in southeastern forested floodplains are negligible)

N = number of transects

l = length of transect in feet

For stems in the 3-in. (76-mm) size class, use the following formula:

$$\text{tons/acre} = \frac{\left(11.64 \times \sum d^2 \times s \times a \times C\right)}{N \times l} \tag{7}$$

where $\sum d^2$ = the sum of squared diameter for each intersecting stem

When large areas with many different tree species are being inventoried, it is practical to use composite values and approximations for diameters, specific gravities, and nonhorizontal angle corrections. For example, if composite average diameters, composite average non-horizontal correction factors, and best approximations are used for the southeast, the preceding value for stems in the 0.25- to ≤1.0-in. (6- to ≤25-mm) size class simplifies to:

$$\text{tons/acre} = \frac{(2.24n)}{N \times l} \tag{8}$$

For stems in the >1.0- to ≤3.0-in. (>25 to ≤76-mm) size class the formula simplifies to:

$$\text{tons/acre} = \frac{(21.4n)}{N \times l} \tag{9}$$

For stems in the ≤3.0-in. (≤76-mm) size class the formula simplifies to:

$$\text{tons/acre} = \frac{\left[6.87\left(\sum d^2\right)\right]}{N \times l} \tag{10}$$

(5) Sum the tons/acre for the three size classes and convert to cubic feet/acre:

$$\text{cubic feet/acre} = \frac{(\text{tons/acre} \times 32.05)}{0.58} \tag{11}$$

(6) Convert cubic feet/acre to cubic meters/acre by multiplying cubic feet/acre by 0.072.

(7) Report woody debris volume in m^3/ha.

In west-central peninsular Florida reference wetlands, the volume of woody debris ranged from 0 to 304 m^3/ha (Appendix D). Based on data from reference standard sites, a variable subindex of 1.0 is assigned to sites with woody debris between 60 and 150 m^3/ha (Figure 17). Below 60 m^3/ha the subindex decreases linearly to 0. This range of values included reference sites that had been converted to agriculture and had little or no woody debris, sites in early stages of succession with low volumes of woody debris, and sites in the middle stages of succession with a volume of woody debris between 4 and 56 m^3/ha. The decrease in the variable subindex is based on the assumption that lower volumes of woody debris indicate an inadequate reservoir of organic carbon and an inability to contribute to organic carbon export. Above 150 m^3/ha the subindex decreases linearly to 0 at 250 m^3/ha. This is based on the assumption that increasingly higher volumes of woody debris indicate that nutrient cycles are out of balance and that high levels of nutrients are locked up in the long-term storage component and unavailable for primary production in the short term. This situation occurs after logging, catastrophic wind damage, or lightning strikes.

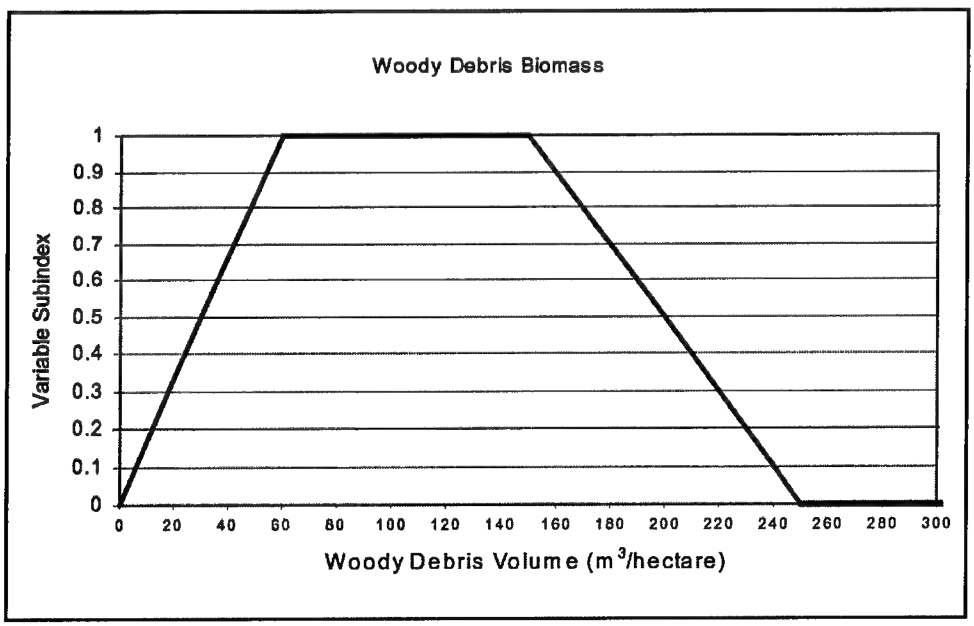

Figure 17. Relationship between woody debris biomass and functional capacity

Functional Capacity Index

The aggregation equation for deriving the FCI for Cycling Nutrients is as follows:

$$FCI = \left[\frac{\left(\frac{V_{TBA} + V_{SSD} + V_{GVC}}{3} \right) + \left(\frac{V_{AHOR} + V_{OHOR} + V_{WD}}{3} \right)}{2} \right] \tag{12}$$

In the model equation, the capacity of the riverine wetland to cycle nutrients depends on two characteristic parts. The presence of all strata of the plant community is represented by the model variables V_{TBA}, V_{SSD}, and V_{GVC} in the first part of the equation. These partially compensatory variables (Smith and Wakeley 2001) are combined using an arithmetic mean. This is based on an assumption of equal importance for each strata of the plant community, and the fact that the total loss of one of the strata (i.e., a variable subindex of 0.0) does not cause nutrient cycling to cease, just to be reduced.

The second part of the model equation, the presence of the long- and short-term detrital and soil components, is represented by the variables V_{AHOR}, V_{OHOR}, and V_{WD}. These partially compensatory variables are averaged based in the assumption that all detrital components are given equal importance in nutrient cycling.

The two parts of the model equation are averaged because the production and decomposition processes in nutrient cycling are considered to be interdependent and equally important. Hence a characteristic level of nutrient cycling will not be achieved (i.e., an FCI of 1.0) if nutrient cycling processes related to primary production or decomposition are reduced. An arithmetic rather than a geometric mean is used in recognition of the fact it is possible under certain situations for variable subindices to drop to 0.0 for short periods of time. For example, high-velocity currents associated with overbank floods can physically remove detrital components for short periods of time. However, as long as the tree strata of plant community are present, the primary production component of nutrient cycling will continue, detrital stocks will be replenished quickly, and nutrient cycling will continue at high levels.

Function 4: Remove and Sequester Elements and Compounds

Definition

A riverine wetland has the capacity to remove and temporarily immobilize imported nutrients, metals, and other elements introduced into the system via overbank flooding and overland flow from uplands. The term removal

implies semipermanent loss of elements and compounds (e.g., deep burial in sediments) whereas the term sequestering implies relatively long-term accumulation of elements and compounds (e.g., storage in plant biomass). Elements include macronutrients such as nitrogen and phosphorus, and heavy metals such as zinc and chromium; compounds include pesticides. Mechanisms of removal and sequestering include sorption, chemical precipitation, hydrolysis, and similar processes. This function differs from the nutrient cycling function, which focuses on internal fluxes of nutrients within a period of one year or less. A quantitative measure of this function is the amount of elements and compounds removed and/or retained per unit area per unit time (i.e., $g/m^2/year$).

Rationale for selecting the function

The ability of wetlands to intercept elements and compounds from upland or aquatic nonpoint sources is widely documented (Lowrance et al. 1984; Peterjohn and Correll 1984; Cooper et al. 1987; Faulkner and Richardson 1989; Johnston 1991). Elements and compounds in surface water and/or groundwater that come in contact with sediments may be removed from a site or rendered "noncontaminating" because they are broken down into innocuous and biogeochemically inactive forms. From the mid-1970s to the mid-1980s, extensive effort in research and development was invested in testing wetlands as sites for tertiary treatment of wastewaters. Summaries of these projects are available in U.S. Environmental Protection Agency (1983), Godfrey et al. (1985), and Ewel and Odum (1984). Riverine wetlands in headwater positions and lower order streams are strategically located to intercept nutrients and contaminants before they reach streams (Brinson 1990). Sources of elements and compounds include precipitation, atmospheric deposition, surface flow, and overbank flood events. The primary benefit of this function is simply that the removal and sequestration of elements and compounds by riverine wetlands reduce the load of nutrients, heavy metals, pesticides, and other pollutants in rivers and streams. This translates into better water quality and aquatic habitat in rivers and streams.

Characteristics and processes that influence the function

There are two categories of characteristics and processes that influence the capacity of riverine wetlands to remove and sequester elements and compounds. The first deals with the mechanisms by which elements and compounds are transported to the wetland, and the second with the structural components and biogeochemical processes involved in removal or sequestration of the elements and compounds.

Elements and compounds are imported to riverine wetlands by a variety of mechanisms and from a variety of sources. They include dry deposition and precipitation from atmospheric sources, overbank flooding from alluvial sources, and overland flow, channelized flow, interflow, shallow groundwater

flow, and colluvial material from upland sources. Some of the mechanisms such as dry deposition and precipitation typically account for a small proportion of the total quantity of elements and compounds imported to the riverine wetland. The mechanisms that bring nutrients and compounds to the wetland from alluvial and upland sources are more important in terms of both the quantity of elements and compounds and their likelihood of being impacted.

Once nutrients and compounds arrive in the riverine wetland they may be removed and sequestered through a variety of biogeochemical processes. Biogeochemical processes include complexation, chemical precipitation, adsorption, denitrification, decomposition to inactive forms, hydrolysis, uptake by plants as well as other processes (Kadlec 1985; Faulkner and Richardson 1989; Johnston 1991). A major mechanism that contributes to removal of elements and compounds from water entering a wetland is reduction. Denitrification will not occur unless the soil is anoxic and the redox potential falls below a certain level. When this occurs nitrate (NH_3^-) removed by denitrification is released as nitrogen gas to the atmosphere. In addition, sulfate is reduced to sulfide, which then reacts with metal cations to form insoluble metal sulfides such as CuS, FeS, PbS, and others.

Another major mechanism for removal of elements and compounds is by adsorption to electrostatically charged soil particles. Clay particles and particulate organic matter are the most highly charged soil particles and contribute the most to the cation exchange capacity (CEC) of the soil. Cation exchange is the interchange between cations in solution and other cations on the surface of any surface active material (i.e., clay colloid or organic colloid). The sum total of exchangeable cations that a soil can absorb is the CEC. The CEC of a soil is a function of the amount and type of clay and the amount of organic matter in the soils. Further, organic matter is a food source for microbes involved in various microbial processes (i.e., reduction-oxidation reactions, denitrification, microbial pesticide degradation, etc.).

Nitrogen in the ammonium (NH_4^+) form may be sequestered by adsorption to clay minerals in the soil. Phosphorus can only be sequestered, not truly removed. The soluble orthophosphate ion (PO_4^{3-}) may be specifically adsorbed (fixed) to clay and Fe and Al oxide minerals (Richardson 1985), which are generally abundant in riverine wetlands. Likewise, heavy metals can be sequestered from incoming waters by adsorption onto Fe and Al oxide minerals, or by chemical precipitation as insoluble sulfide compounds. Direct measurement of concentrations of these soil components is beyond the scope of rapid assessment. However, soils with pH of 5.5 or less generally have Al oxide minerals present that are capable of adsorbing phosphorus and metals. Fe oxides are reflected in brown or red colors in surface or subsurface horizons, either as the dominant color or as redox concentrations. If the Fe oxide minerals become soluble by reduction, adsorbed phosphorus is released into solution. Annual net uptake of phosphorus by growing vegetation, although significant, usually represents a small quantity relative to other soil/sediment sinks of phosphorus (Brinson 1985).

Riverine wetlands also retain nutrients and compounds by storing and cycling them between plant, animal, detrital, and soil compartments (Patrick and Tusneem 1972; Kitchens et al. 1975; Brinson 1977; Day, Butler, and Conner 1977; Mitsch, Dorge, and Wiemhoff 1979; Yarbro 1983; Brinson, Bradshaw, and Kane 1984; Yarbro et al. 1984).

Description of model variables

Frequency of Overbank Flooding (V_{FREQ}). This variable is defined as the frequency with which water in an adjacent stream overtops its banks and inundates the riverine wetland (Ainslie et al. 1999). This variable is quantified by determining the return interval in years of overbank flooding. In the context of this function, overbank flood frequency indicates how often peak seasonal discharge inundates a riverine wetland and allows surface water to be temporarily stored. Recurrence interval in years is used to quantify this variable. This variable is best derived from streamflow data within the watershed, but these data are not always available. Flood frequency analyses of annual peak flow data, typically by techniques outlined in the USGS "Guidelines for Determining Flood Frequency" (1982) using a log-Pearson Type III distribution (Benson 1968), provides peak discharges for selected recurrence intervals. Peak discharge data can be used at selected sites to determine overbank flooding. Several methods are available for more rapidly estimating recurrence interval (see description of this variable under Function 1).

In peninsular Florida reference wetlands, using the regional curve or equations for the ratio or regression approach described in Appendix C produced the recurrence interval ranging from 1 to 100 years (Appendix D). Based on the range of values from reference standard sites, a variable subindex of 1.0 is assigned to recurrence intervals less than or equal to 3.0 years (Figure 18). Longer recurrence intervals are assigned a linearly decreasing subindex down to 0.1 at a recurrence interval of 10 years. This is based on the assumption that where entrenchment, channelization, or levees effectively increase the depth of the stream channel, a greater discharge is required to overtop the bank and inundate the riverine wetland. Since greater discharges occur less frequently, the volume of surface water that is temporarily stored in riverine wetlands is less than what characteristically is stored at reference standard sites in both the short and long term. The rationale for the rate at which the subindex drops to 0.1 (i.e., 1.0 to 0.1) is based on the assumption that as frequency of overbank flow increases, the capacity of the wetland to store annual peak discharges decreases to one-tenth the amount of water stored over a period of 10 years under reference standard conditions. Model validation will help to define the actual nature of this relationship. Recurrence intervals greater than 10 years are assigned a subindex of 0.1, based on the assumption that even at longer recurrence intervals, riverine wetlands provide some floodwater storage, albeit infrequently.

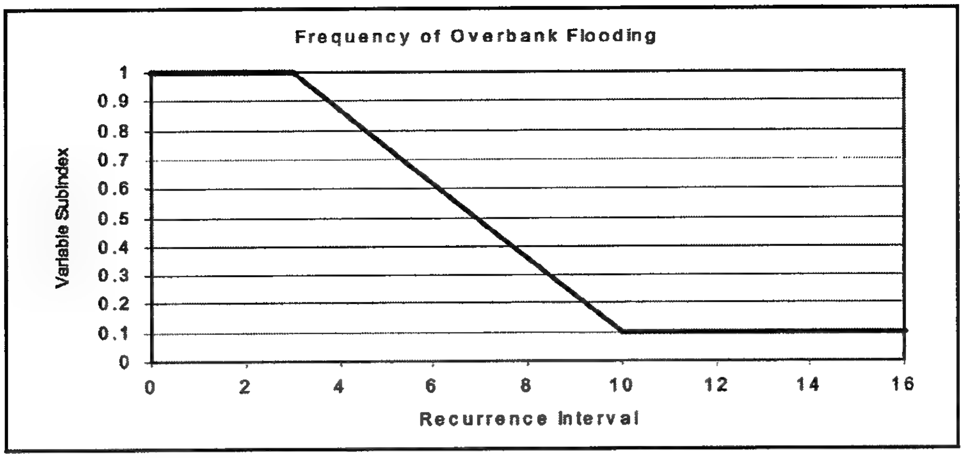

Figure 18. Relationship between frequency of overbank flooding and functional capacity

Soil Clay Content (V_{CLAY}). This variable represents the proportion of the total charge that originates from the clay fraction or separate. One of the mechanisms that contributes to the retention of elements and compounds is adsorption to charged sites on soil particles. The adsorption capacity of a soil is reflected by the CEC and anion exchange capacity (AEC), which originate from electrostatic charges on organic and mineral particles in the soil. Within the mineral fraction, most of the charge originates from clay-sized particles (<0.002 mm) because of surface area and types of minerals present in this size class. The amount and mineralogy of the clay (i.e., montmorillonite, kaolinite, quartz, etc.) determine the total charge, either positive or negative, derived from clay particles. The laboratory characterization data (Carlisle et al. 1978, 1981, 1985, 1988, 1989, 1990) show that the clay mineralogy, from the standpoint of this assessment approach, is relatively uniform in this area. Thus the amount of clay within a horizon can be used to reflect the total nonorganic charge for the horizon.

There are two alternatives for measuring the soil clay content:

(1) Measure the soil particle size distribution in a laboratory on samples taken from the field.

(2) Estimate the percentage of clay from field texture determinations done by the "feel" method. Appendix C describes the procedure for estimating texture class by feel. Based upon the soil texture class, determine the percentage of clay from the soil texture triangle. The soil texture triangle contains soil texture classes and the corresponding percentages of sand, silt, and clay that compose each class. The median value from the range of percent clay is used to calculate the weighted average. The median value of percent clay of each soil texture class is listed in Table 10.

Calculate a weighted average of the percent clay by averaging the percent clay from each of the soil layers to a depth of 20 in. (0.5 m). For example,

Table 10
Clay Content, percent, of Soil Texture Classes

Texture Class	Range of Clay Content, %	Median Value of Clay Content, %
Sand	0-10	5
Silt	0-13	7
Loamy sand	0-15	8
Sandy loam	0-20	10
Silt loam	0-27	14
Loam	7-27	17
Sandy clay loam	20-35	28
Silty clay loam	27-40	34
Clay loam	27-40	34
Sandy clay	35-55	45
Silty clay	40-60	50
Clay	40-100	70

if the A layer occurs from a depth of 0-6 in. (0.15 m) and has 10 percent clay, and the B layer occurs from a depth of 7-20 in. (0.18-0.5 m) and has 20 percent clay, then the weighted average of the percent clay for the top 20 in. (0.5 m) of the profile is $[(6 \times 10) + (14 \times 20)]/20 = 0.17$ or 17 percent.

If the clay content differs in several areas of the wetland, calculate a weighted average of the percent clay from each of these areas of the wetland. For example, if 70 percent of the wetland area has 10 percent clay, and 30 percent of the wetland area has 40 percent clay then the weighted average of the percent clay for that wetland is [(10 percent × 70 percent) + (40 percent × 30 percent)] × 100 percent = 19 percent.

In the reference wetlands, percent clay ranged from 5 percent to 64 percent (Appendix D). Based on data from reference standard sites, a variable subindex of 1.0 is assigned to sites with percent clay between 9 percent to 45 percent (Figure 19). Below 9 percent the subindex decreases linearly to 0.0. When percent clay content is greater than 45 percent, a linearly decreasing subindex is assigned to 0.1 at 100 percent. This is based on the assumption that increasingly higher clay content adversely affects the wetland capacity to remove and sequester elements and compounds. For example, higher than characteristically normal clay content will impede movement of elements and compounds in water to deeper soil layers. Extremely high clay content will cease vegetation growth, and this will adversely affect nutrient uptake by plants and formation of soil O and A horizon biomass. Exceptionally high percent clay in soils can result from activities such as filling or discharge of clay-laden wastewater from phosphate mining.

Hydric Soil Indicators (V_{HSOIL}). This variable represents the reduction and oxidation property of the soil in a riverine wetland. Hydric soil indicators include carbon features, redoximorphic features, or other indicators.

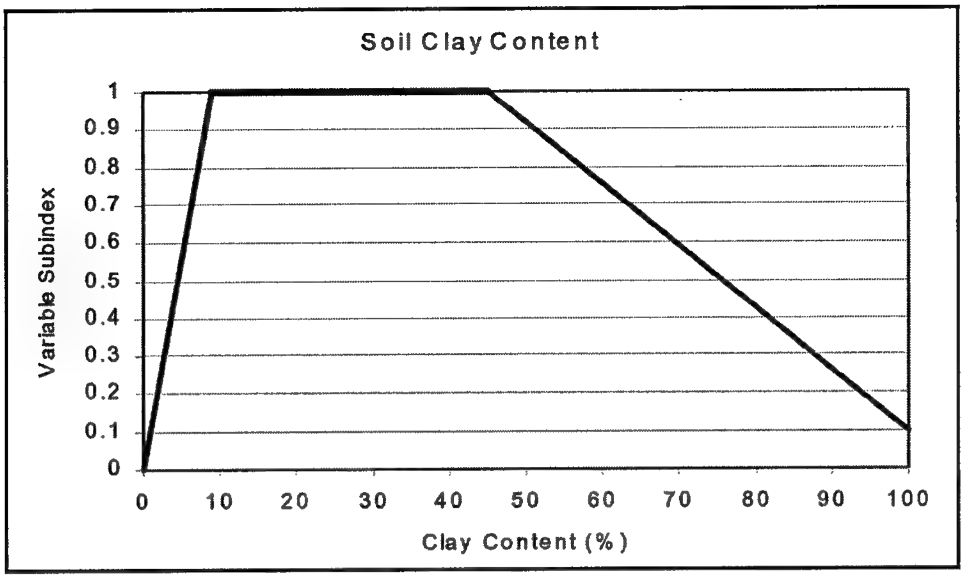

Figure 19. Relationship between soil clay content and functional capacity

These indicators are discussed in the publication by the National Resources Conservation Service (USDA NRCS 1998). The presence of hydric soil indicators implies adequate soil inundation or saturation for a sufficient duration to induce reduction in the upper part of the soil profiles. It is assumed that soil reduction in the upper part has more influence on the wetland ecosystem than at greater depths. Periodic reduction and oxidation of soils is a major mechanism in the removal of elements and compounds in the soil profile.

Among the hydric soil indicators, some indicators are evidence of a characteristically seasonal high-water table (SHWT) at or above the soil surface. Examples of these indicators are muck, mucky mineral, and sulfidic odor (Hurt, Watts, and Carlisle 2000). For the purpose of this procedure, these indicators are categorized as inundation indicators characteristic of riverine wetland soils that develop dominant hydric soil features from overbank flooding. Because these soil features are often difficult to assess without the assistance of an experienced soil scientist, other indicators of inundation may be evaluated. Some of these indicators of inundation are aquatic mosses, liverworts, and lichen lines elevated on tree trunks, elevated hydric adventitious roots, sediment deposition, stained leaves, drift lines and rafted debris, vegetation scouring, and elevated water marks on tree trunks.

Organic bodies, stratified layers, dark surface, sandy redox, stripped matrix, and depleted matrix (Hurt, Watts, and Carlisle 2000), are examples of saturation indicators. Soils with saturation indicators have an SHWT within 6 in. (0.15 m) (for sandy soils) or 12 in. (0.3 m) (for loamy and clayey soils) of the soil surface. The SHWT in these soils is below the soil surface and may locate at any depth within 6 in. (0.15 m) (or 12 in. (0.3 m)). In the soil layer from the surface to the depth where the SHWT locates,

anaerobic conditions may not exist. Soils with inundation indicators achieve greater reducing conditions in the top layer than the soils with saturation indicators.

Determine this variable with the following procedure:

(1) Observe the top 6 in. (0.15 m) of sandy soil or 12 in. (0.3 m) of loamy or clayey soil, and determine if any indicators listed in the USDA NRCS (1998) are dominant for inundation, saturation, or absence.

(2) Observe the site for the dominance of inundation indicators such as aquatic mosses, liverworts, and lichen lines elevated on tree trunks, elevated hydric adventitious roots, sediment deposition, stained leaves, drift lines and rafted debris, vegetation scouring, and elevated water marks on tree trunks.

(3) Record the indicator(s), if any. Report these indicators as inundation, saturation, or absence by choosing the most dominant indicators if any.

No attempt is made to develop a linear relationship between this variable and functional capacity based on the degree or expression of hydric soil indicators. In the reference wetlands, hydric soil indicators range from inundation to absence (Appendix D). Based on the presence of inundation indicators at all reference standard sites, a variable subindex of 1.0 was assigned to the presence of inundation indicators (Figure 20). Sites with inundation indicators are assigned a higher subindex value because reducing conditions are greater in the top layer of the soils and removal of elements and compounds is greater during flood events. Sites with saturation indicators are assigned a subindex of 0.7. Sites where no hydric soil indicator is observed are assigned a subindex of 0.1 based on the assumption that even

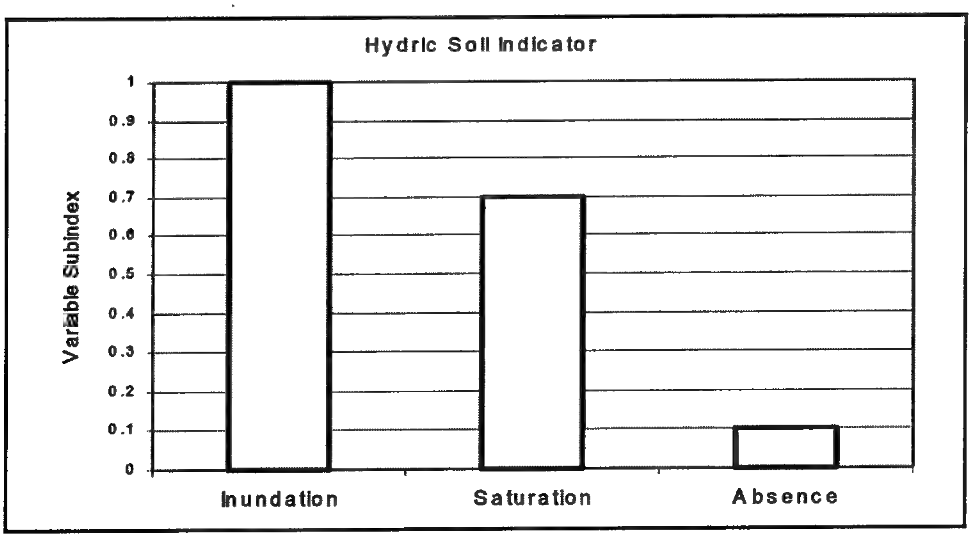

Figure 20. Relationship between hydric soil indicators and functional capacity

in the absence of hydric soil indicators, reduction takes place at some low level.

Water Table Depth (V_{WTD}). This variable represents the depth to SHWT in the riverine wetland. In the context of this function, this variable indicates whether or not groundwater contributes to maintaining a hydrologic regime that is conducive to the biogeochemical processes that remove and sequester elements and compounds.

Depth to the SHWT is used to quantify this variable. Measure it with the following procedure:

(1) Determine the depth to the current SHWT using the following, in order of accuracy and preference:

(a) Groundwater monitoring well data collected over several years.

(b) Soil morphological features including redoximorphic features such as iron concentrations or the presence of a reduced soil matrix (Hurt, Watts, and Carlisle 2000; USDA NRCS 1998; Verpraskas 1994), remembering that some redoximorphic features reflect a soil that has been anaerobic at some time in the past, but that do not necessarily reflect current conditions.

(c) Presence of an SHWT according to the soil and water features table in modern county soil surveys. In situations where the fluctuation of the water tables has been altered as a result of raising the land surface above the water table through the placement of fill, the installation of drainage ditches, or drawdown by water supply wells, the information in the soil survey is no longer useful. Under these circumstances the use of well data or redoximorphic features that indicate current conditions may be the only way to obtain the necessary information.

(2) Report depth to SHWT in inches.

In west-central peninsular Florida reference wetlands, the depth to SHWT ranged from 0 to more than 24 in. (0.6 m) below the surface (Appendix D). Based on the range of values from reference standard sites, a variable subindex of 1.0 was assigned to SHWT "depths" between 0 (i.e., ground surface) and 6 in. (0.15 m) below the ground (Figure 21). As the depth to the SHWT increases (i.e., is further below the surface of the ground) the subindex decreases linearly to 0 at a depth of 24 in. (0.6 m). This is based on the assumption that the capacity of the riverine wetland to maintain the degree of soil saturation required for characteristic biogeochemical processes and plant and animal communities is dependent on maintaining a characteristic high-water table near or above the surface of the ground.

O Horizon Biomass (V_{OHOR}). This variable represents the total mass of organic matter in the O horizon. The O horizon is defined as the soil

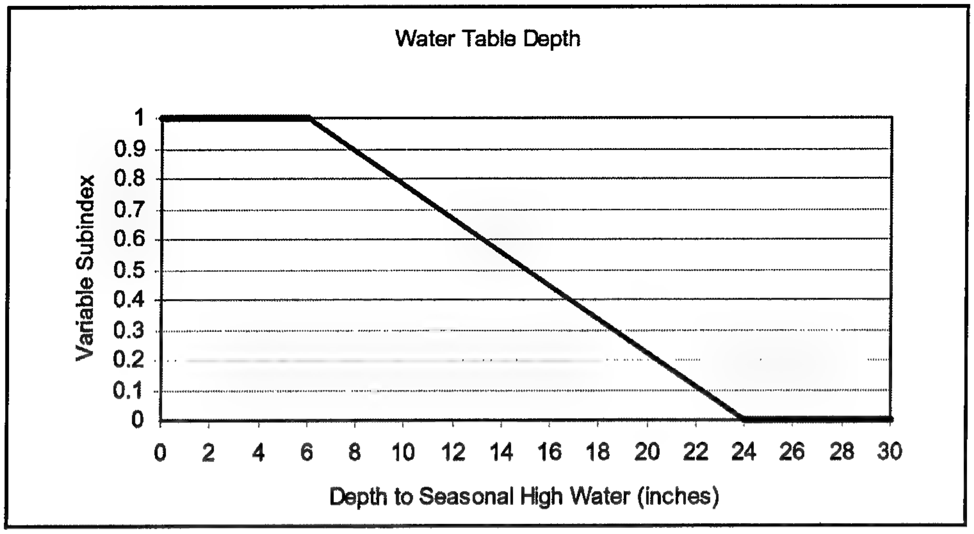

Figure 21. Relationship between water table depth and functional capacity (to convert inches to meters, multiply by 0.0254)

layer dominated by organic material that consists of recognizable or partially to highly decomposed organic matter such as leaves, needles, sticks, or twigs <0.6 cm in diameter, flowers, fruits, insect frass, moss, or lichens on or near the surface of the ground (USDA SCS 1993). The O horizon is synonymous with the terms detritus or litter layer used by other disciplines. In the context of this function the O horizon represents a component of the organic matter that can sequester imported elements and compounds by adsorption.

Percent cover of the O soil horizon is used to quantify this variable. The procedure for measuring it is described under the description of this variable under Function 3.

In west-central peninsular Florida reference wetlands, percent O horizon cover measured 100 percent (Appendix D). Based on data from reference standard sites, a variable subindex of 1.0 is assigned when the O soil horizon is 100 percent (Figure 22). As O horizon cover decreases, a subindex linearly decreasing to zero at zero percent cover is assigned. The rate at which the subindex decreases and the selection of zero as the subindex at 0 percent cover, are based on the assumption that the relationship between O soil horizon cover and organic carbon export is linear, and that a decreasing amount of biomass in the tree, sapling, shrub, and ground vegetation strata of the plant community is reflected in lower percent O soil horizon cover. When percent O soil horizon declines to zero, sequestration by organic matter has essentially ceased. These assumptions could be validated using the independent, quantitative measures of function defined previously.

A Horizon Biomass (V_{AHOR}). This variable represents total mass of organic matter in the A horizon. The A horizon is defined as a mineral soil horizon that occurs at the ground surface, or below the O soil horizon, and consists of an accumulation of unrecognizable decomposed organic matter

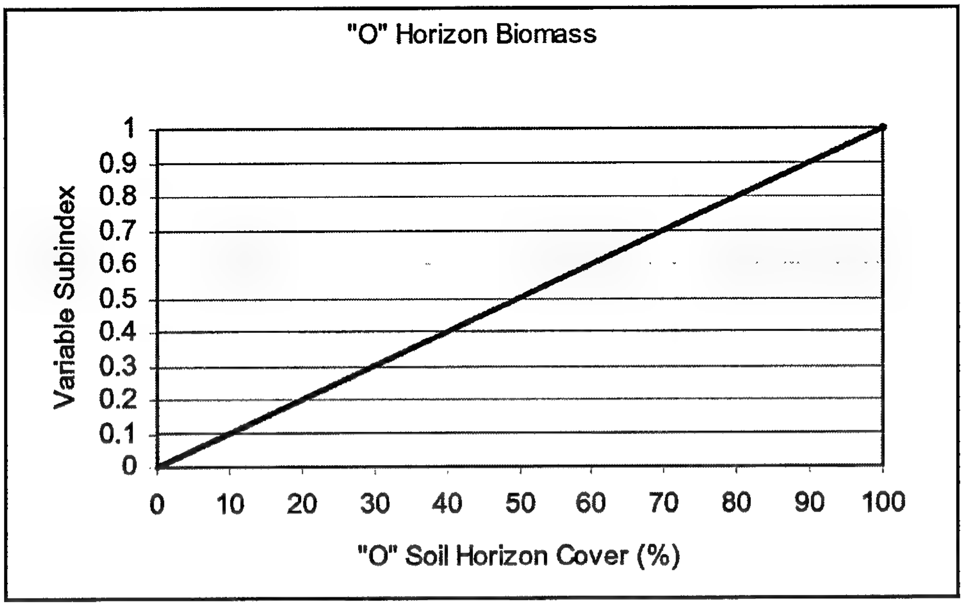

Figure 22. Relationship between O horizon biomass and functional capacity

mixed with mineral soil (USDA SCS 1993). In addition, for the purposes of this procedure, in order for a soil horizon to be considered an A horizon it must be at least 7.5 cm (3 in.) thick, and have a Munsell color value less than or equal to 4. In the context of this function, the A horizon represents another reservoir of organic matter that is available to adsorb elemental compounds.

Percent cover of the A soil horizon is used to quantify this variable. Measure it with the procedure described under the description of this variable under Function 3.

In west-central peninsular Florida reference wetlands, A horizon cover ranged from 0 to 100 percent (Appendix D). Based on data from reference standard sites, a variable subindex of 1.0 is assigned when the percent cover of the A horizon is 100 percent (Figure 23). As the percent cover of the A horizon decreases, a subindex linearly decreasing to zero at zero percent cover is assigned. This is based on the assumption that the relationship between percent A horizon and the capacity to remove and sequester compounds is linear and reflects decreasing contribution to A horizon biomass by the tree, sapling, shrub, and ground vegetation strata of the plant community. Sites that have been converted to agricultural crops may have low coverage of the A horizon due to the oxidation of the organic carbon following tillage (Ismail, Blevins, and Frye 1994).

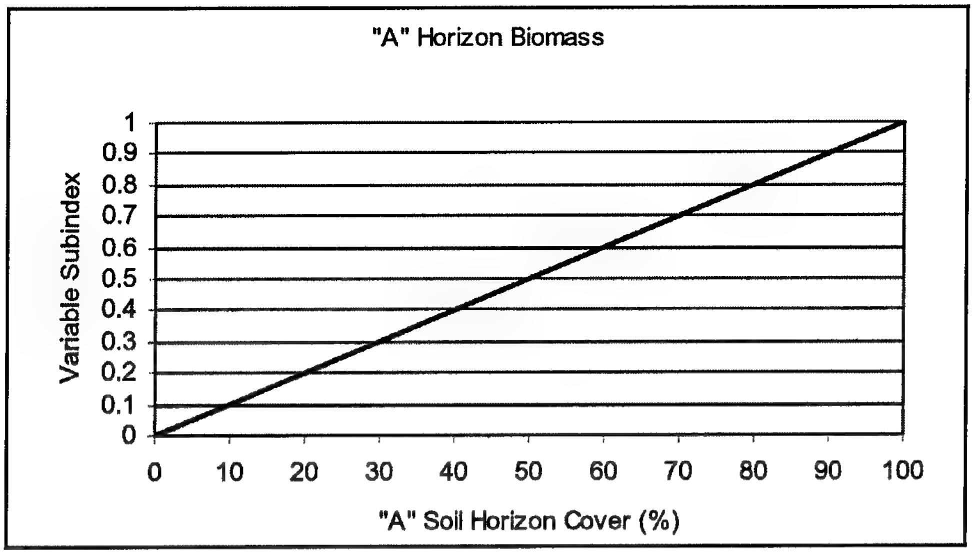

Figure 23. Relationship between A horizon biomass and functional capacity

Functional Capacity Index

The assessment model for deriving the FCI for Removal and Sequestration of Elements and Compounds is as follows:

$$FCI = \left[\left(\frac{V_{FREQ} + V_{WTD}}{2}\right) \times \left(\frac{V_{CLAY} + V_{HSOIL} + V_{AHOR} + V_{OHOR}}{4}\right)\right]^{1/2} \tag{13}$$

In the first part of the model, recurrence interval V_{FREQ} indicates whether or not elements and compounds are being imported from alluvial sources. SHWT depth V_{WTD} indicates whether or not groundwater contributes to maintaining a hydrologic regime that is conducive to the biogeochemical processes that remove and sequester elements and compounds. The two variables are partially compensatory based on the assumption that they are independent and contribute equally to performance of the function. The two variables are combined using an arithmetic mean because elements and compounds will continue to be imported to the wetland even if the value of the V_{WTD} subindex drops to 0.0.

In the second part of the model, four variables, all indicating different mechanisms for removing or sequestering imported elements and compounds, are partially compensatory since they are assumed to be independent and contribute equally to performance of the function. V_{CLAY}, V_{AHOR}, and V_{OHOR} represent the adsorptive capacity of soils due to clays and organic matter, while V_{HSOIL} represents the reducing environment and level of microbial activity needed for this function to occur. The four are combined using an arithmetic mean because elements and compounds will continue to be removed and sequestered even after V_{CLAY}, V_{AHOR}, and V_{OHOR} variable subindices drop to 0.

The two parts of the equation are partially compensatory, and combined using a geometric mean because if either subpart of the equation 0s, then the functional capacity should also drop to 0. This simply means that if elements and compounds are no longer imported to the riverine wetland, or if all the mechanism that exist within the wetland for removing and sequestering elements and compounds are absent, then the riverine wetland has no capacity to remove elements and compounds.

Function 5: Retain Particulates

Definition

Retain particulates refers to the capacity of a wetland to physically remove and retain inorganic and organic particles >0.45 μm from the water column. Retention applies to particulates from both onsite and offsite sources. A quantitative measure of this function is the amount of particulates per unit area per unit time (i.e., g/m^2/year).

Rationale for selecting the function

This is an important function because sediment accumulation contributes to the nutrient economy of an ecosystem. Deposition of inorganic particulates elevates the surface and changes topographic complexity, which has implications for hydrologic, biogeochemical, and biotic processes. Particulates in the form of organic matter are important for detrital food webs and nutrient cycling. This function also reduces stream sediment load and woody debris load that would otherwise be transported downstream.

This function differs from cycling of nutrients and removal and sequestering of elements and compounds because the emphasis is on physical processes.

Characteristics and processes that influence the function

Flooding from overbank flow of alluvial streams is a major transport vector for particulates to reach floodplain wetlands. Three primary modes of water and sediment movement have been identified: (a) in-channel flow; (b) overbank flooding; and (c) overland flow (Molinas et al. 1988). For each mode, sediment movement can be described by the processes of initiation of motion (a function of the energy available and the nature of the sediment), transport, and deposition. Once sediment particles are set in motion, the capacity of flows to transport sediment is primarily a function of water velocity, depth of flow, floodplain slope, and size of particles being transported. Scour and deposition processes are adjustments to maintain a balance between the amount of sediment that overbank flows can carry and the amount of sediment transported. Deposition occurs when the sediment

load exceeds the ability of the water flow to carry the load (i.e., transport capacity). When the sediment transport capacity exceeds the amount of sediment being carried, scouring occurs.

In overbank flooding situations, water velocities decrease as water spreads onto the adjacent floodplain resulting in deposition as the transport capacity is reduced. Low-gradient, riverine, forested wetlands typically have well-developed canopy and litter layer structures that absorb the kinetic energy of precipitation (i.e., less energy to detach sediment). These wetlands have high surface roughness coefficients that produce low velocities and low transport capacities thus retaining sediment within the wetland and producing deposition from overbank flows. However, much of the velocity reduction, and resulting deposition, is accounted for by floodwaters spreading out over large, flat areas rather than by the surface roughness of the site (Molinas et al. 1988). The same hydrodynamics that facilitate sedimentation may also capture and retain existing organic particulates. For example, deposition of silt following litterfall appears to reduce the potential for leaves to become suspended by currents and exported (Brinson 1977).

Description of model variables

Frequency of Overbank Flooding (V_{FREQ}). This variable represents the frequency at which water from a stream overtops its banks (i.e., exceeds channel-full discharge) and inundates riverine wetlands on the floodplain. Overbank flood frequency is the manifestation of current conditions in the watershed and channel at the spatial scale of the riverine wetland. In the context of this function, overbank flooding is the mechanism by which particulates are imported to the riverine wetland from alluvial sources.

Recurrence interval in years is used to quantify this variable. The procedure for measuring it is described under the description of this variable under Function 1.

In west-central peninsular Florida reference wetlands, using the regional curve or equations for the ratio or regression approach produced the recurrence interval ranging from less than 1 to 100 years (Appendix D). Based on the range of values from reference standard sites, a variable subindex of 1.0 is assigned to recurrence intervals ≤3 years (Figure 24). Longer recurrence intervals are assigned a linearly decreasing subindex to 0.1 at a recurrence interval of 10 years. This is based on the assumption that where entrenchment, channelization, or levees effectively increase the depth of the stream channel, a greater discharge is required to overtop the bank and inundate the riverine wetland. Since greater discharges occur less frequently, the frequency at which surface water that is temporarily stored and the amount of sediment delivered to riverine wetlands are less than what characteristically occurs at reference standard sites. The rationale for the rate at which the subindex drops to 0.1 (i.e., 1.0 to 0.1) is based on the assumption that as frequency increases, the capacity of the wetland to retain particulates from annual peak discharges decreases to one-tenth the

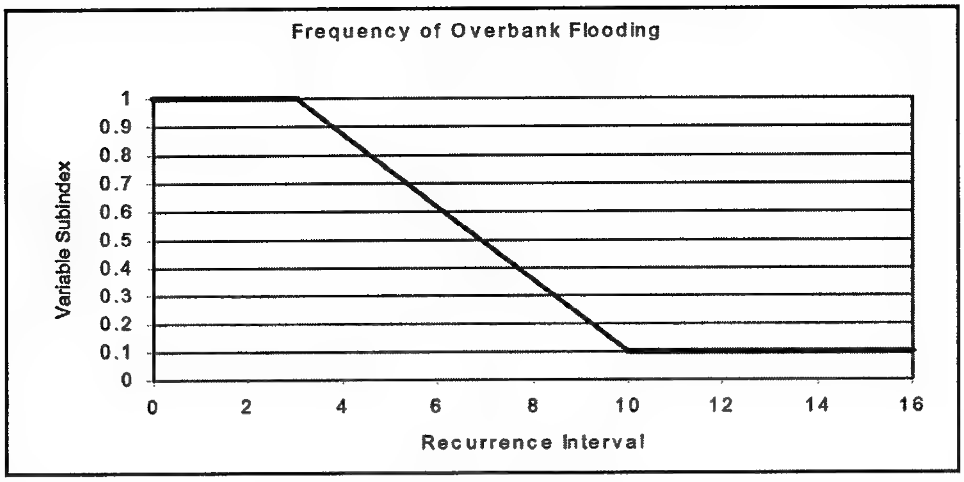

Figure 24. Relationship between frequency of overbank flooding and functional capacity

amount of particulates retained over a period of 10 years under reference standard conditions. Model validation will help to define the actual nature of this relationship. Recurrence intervals greater than 10 years are assigned a subindex of 0.1. This is based on the assumption that even at longer recurrence intervals, riverine wetlands provide some floodwater storage and particulate retention, albeit infrequently. Again, conceptual arguments can be made for decreasing the subindex to 0, but it is difficult to determine at what point an increasing recurrence interval begins to significantly influence the ecological processes linked to overbank flooding.

Floodplain Storage Volume (*V_{STORE}*). This variable represents the volume that is available for storing surface water during overbank flood events. In peninsular Florida, the loss of storage volume is usually a result of dikes, roads, levees, or other man-made structures that reduce the effective width of the floodplain. In the context of this function, this variable is designed to detect changes in storage volume that result from these types of structures. A decrease in storage due to a levee, road, or other structure indicates a commensurate decrease in sedimentation since flows transporting the sediment bypass the wetland. Measure this variable using the definitions and procedure described under the description of this variable in Function 1.

In peninsular Florida reference wetlands, the ratio of floodplain width to channel width ranged from 1 to 400 (Appendix D). Based on the range of values at reference standard wetlands, a variable subindex of 1.0 is assigned to ratios greater than or equal to 30 for this variable (Figure 25). Smaller ratios are assigned a linearly decreasing subindex down to 0 at a ratio of 1. This is based on the assumption that the ratio of floodplain width to channel width is linearly related to the capacity of the riverine wetlands to temporarily store surface water.

Floodplain Slope (*V_{SLOPE}*). This variable represents various channel and floodplain features in the vicinity of the riverine wetland. The relationship

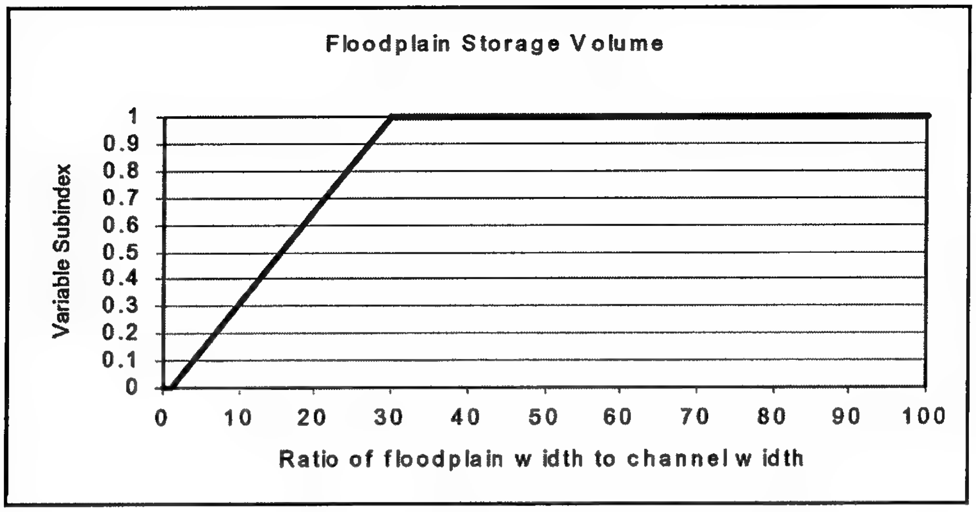

Figure 25. Relationship between floodplain storage volume and functional capacity

between these features and the temporary storage of surface water is based on the proportional relationship between slope, hydraulic radius, channel roughness and velocity in Manning's equation (Equation 1).

The naturally occurring sequentially spaced riffle/pools and the corresponding coarse/fine bed materials in them are controlled by the morphological features of a river channel. Among these features are the hydraulic radius, floodplain slope, and the sinuosity of the channel. These features are critical components that contribute to the energy of the flow. If activities occur to alter these features, the velocity of water can increase and transportation of sediment can increase with less sediment being deposited in the wetland area. Impacts or alterations to the channel or floodplain are used to quantify this variable. Measure it using the procedure given for this variable under Function 1.

If floodplain alterations such as surface mining, fill, or the placement of structures in the channel have occurred, then a value of 0.1 is assigned (Figure 26). If channel alterations such as channel dredging or straightening or other streambed modifications have occurred, the value drops to 0. If no alterations have occurred to the floodplain or channel, then a value of 1.0 is assigned.

Floodplain Roughness (V_{ROUGH}). This variable represents the resistance to the flow of surface water resulting from physical structure on the floodplain. The relationship between roughness and the velocity of the surface water flow is expressed by Manning's equation, which indicates that as roughness increases, velocity decreases and storage time increases (Equation 1). Several factors contribute to roughness including the soil surface, surface irregularities (e.g., micro- and macrotopographic relief), obstructions to flow (e.g., stumps and coarse woody debris), and resistance due to vegetation structure (trees, saplings, shrubs, and herbs). Depth of flow is also an important consideration in determining roughness because

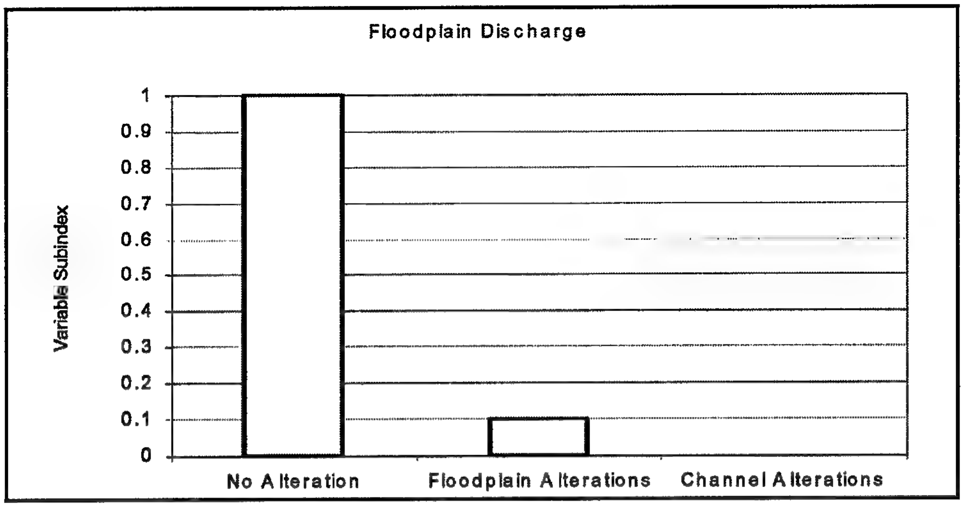

Figure 26. Relationship between floodplain discharge and functional capacity

as water depth increases, obstructions are overtopped and cease to be a source of friction or turbulence causing the roughness coefficient to decrease. Manning's roughness coefficient n is used to quantify this variable. Measure it as described in the description of this variable under Function 1.

In peninsular Florida reference wetlands, Manning's roughness coefficient ranged from 0.04 to 0.27 (Appendix D). These values were based on setting n_{BASE} to 0.026, and adjustment values for the topographic relief component n_{TOPO}, which ranged from 0.0 to 0.02, the obstructions component n_{OBS}, which ranged from 0.0 to 0.05, and the vegetation component n_{VEG}, which ranged from 0.005 to 0.2.

Based on the range of values at reference standard sites, a variable subindex of 1.0 is assigned to Manning's roughness coefficients between 0.14 and greater (Figure 27). Lower roughness coefficients were assigned a

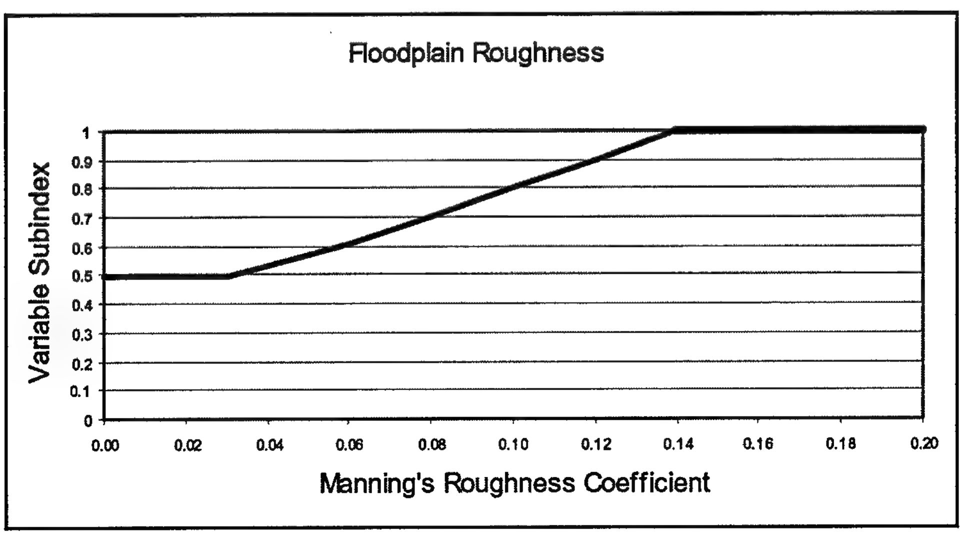

Figure 27. Relationship between floodplain roughness and functional capacity

linearly decreasing subindex down to 0.5 at ≤0.03. This reflects the approximate five-fold increase in flow velocity that occurs as floodplain roughness decreases from 0.15 to 0.03 when holding hydraulic radius and slope constant in Manning's equation.

Functional Capacity Index

The assessment model for calculating the FCI for Retention of Particulates is as follows:

$$FCI = \left[\left(V_{FREQ} \times V_{STORE} \right)^{1/2} \times \left(\frac{V_{SLOPE} + V_{ROUGH}}{2} \right) \right]^{1/2} \tag{14}$$

In this model, the capacity of the riverine wetland to retain particulates depends on two characteristics: the ability of water to get to the site and the ability of the wetland to reduce the velocity of surface water moving through the site. In the first part, the V_{FREQ} variable indicates whether or not changes in the watershed or channel have altered the recurrence interval compared to reference standard sites. The V_{STORE} variable indicates whether or not structural alterations or fill have reduced the volume available for temporarily storing surface water, and thus retaining particulates.

The relationship between the variables is partially compensatory, and they are assumed to contribute equally and independently to the performance of the function (Smith and Wakeley 2001). As the subindices for V_{FREQ} or V_{STORE} decrease, the FCI also decreases. If the subindex for V_{STORE} drops to zero, the FCI will also drop to zero because a geometric mean is used combine V_{FREQ} and V_{STORE} as well as the first and second part of the model equation. This simply means that as the frequency of inundation decreases, or if the floodplain is greatly constricted by levees or ponds, retention of particulates is reduced or eliminated. Use of an arithmetic mean to combine V_{FREQ} or V_{STORE} or the first and second part of the equation would require that subindices for all variables be zero in order for the resulting level of function to be zero which is clearly inappropriate in this situation.

In the second part of the model V_{SLOPE} and V_{ROUGH} reflect the ability of the wetland to reduce the velocity of water moving through the wetland. These variables are also partially compensatory and assumed to be independent and contribute equally to the performance of the function. In this, however, the variables are combined using an arithmetic mean. Generally, this mathematical operation reduces the influence of lower value subindices on the FCI (Smith and Wakeley 2001), which in this case is consistent with the assumption that these variables have less influence on the function than either V_{FREQ} or V_{STORE}.

Function 6: Export Organic Carbon

Definition

This function is defined as the capacity of the wetland to export dissolved and particulate organic carbon through processes including leaching, flushing, displacement, and erosion. A quantitative measure of this function is the mass of carbon exported per unit area per unit time ($g/m^2/year$).

Rationale for selecting the function

The high productivity and close proximity of riverine wetlands to streams make them important sources of dissolved and particulate organic carbon for aquatic food/detrital webs and biogeochemical processes in downstream aquatic habitats (Vannote et al. 1980; Gregory et al. 1991). Dissolved organic carbon is a significant source of energy for the microbes that form the base of the detrital food web in aquatic ecosystems (Dahm 1981; Edwards 1987: Edwards and Meyers 1986). Furthermore, the particulate fraction of organic carbon derived from upland portions of the watershed or produced in situ may be an important source of energy for shredders and filter-feeding organisms (Vannote et al. 1980).

Characteristics and processes that influence the function

Wetlands can be characterized as open or closed ecosystems depending on the degree to which materials are exchanged with surrounding systems (Mitsch and Gosselink 1993). Riverine wetlands normally function as open systems, primarily for two reasons. First, riverine wetlands occur adjacent to stream channels, which are the lowest topographic position in the landscape. Water and sediments pass through the riverine wetlands as gravity moves them toward the stream channel. Second, and of greatest importance in the case of exporting organic carbon, low-gradient riverine wetlands are linked to the stream channel through overbank flooding.

Watersheds with a large proportion of riverine and other wetland types generally export organic carbon at higher rates than watersheds with fewer wetlands (Mulholland and Kuenzler 1979; Elder and Mattraw 1982; Johnston 1991). This may be due to factors including (a) the large quantity of organic matter in the litter and upper soil layers that comes into contact with surface water during overbank flooding, (b) extended periods of inundation that allow significant leaching from organic matter, (c) the rapid leaching of labile carbon from organic matter that has been exposed to water, and (d) the ability of floodwater to transport dissolved and particulate organic carbon from the floodplain to the stream channel. Flooding modifies chemical conditions in alluvial floodplains by depositing and replenishing mineral nutrients and importing and removing organic matter (Wharton et al. 1981).

Description of model variables

Frequency of Overbank Flooding (V_{FREQ}). This variable represents the frequency at which water from a stream overtops its banks (i.e., exceeds channel-full discharge) and inundates riverine wetlands on the floodplain. Overbank flood frequency is the manifestation of current conditions in the watershed and channel at the spatial scale of the riverine wetland. In the context of this function, overbank flooding is the mechanism by which organic carbon is exported from riverine wetlands.

Recurrence intervals in years is used to quantify this variable. The procedure for measuring it is described under Function 1.

In west-central peninsular Florida reference wetlands, using the regional curve or equations from the ratio or regression approach produces a recurrence interval ranging from less than 1 to 100 years (Appendix D). Based on the range of values from reference standard sites, a variable subindex of 1.0 is assigned to recurrence intervals ≤3 years (Figure 28). Longer recurrence intervals are assigned a linearly decreasing subindex to 0.1 at a recurrence interval of 10 years. This is based on the assumption that where entrenchment, channelization, or levees effectively increase the depth of the stream channel, a greater discharge is required to overtop the bank and inundate the riverine wetland. Since greater discharges occur less frequently, the delivery of water to export carbon from the riverine wetlands is less than what characteristically occurs at reference standard sites. The rationale for the rate at which the subindex drops to 0.1 (i.e., 1.0 to 0.1) is based on the assumption that as frequency of overbank flow increases, the capacity of the wetland to retain particulates from annual peak discharges decreases to one-tenth the amount of carbon exported over a period of 10 years under reference standard conditions. Model validation will help to define the actual nature of this relationship. Recurrence intervals

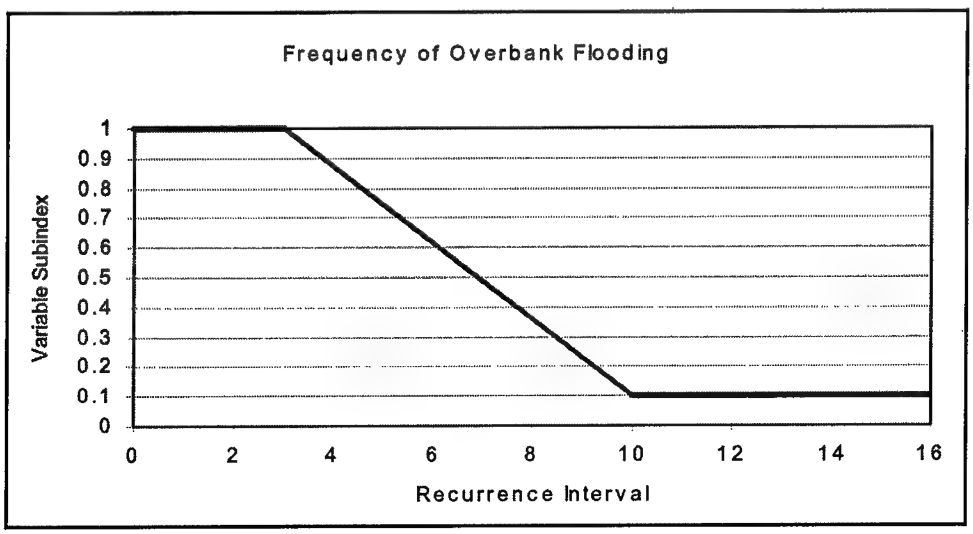

Figure 28. Relationship between frequency of overbank flooding and functional capacity

greater than 10 years are assigned a subindex of 0.1. This is based on the assumption that even at longer recurrence intervals, riverine wetlands provide some floodwater storage and particulate retention, albeit infrequently. Again, conceptual arguments can be made for decreasing the subindex to zero, but it is difficult to determine at what point an increasing recurrence interval begins to significantly influence the ecological processes linked to overbank flooding.

Surface Water Connections ($V_{SURFCON}$). This variable represents the internal network of shallow surface water channels that usually connect the riverine wetland to the stream channel on low-gradient riverine floodplains. Typically, these channels intersect the river channel through low spots in the natural levee. When water levels are below channel-full, these channels serve as the route for surface water, and the dissolved and particulate organic matter it carries, as it moves from the floodplain to the stream channel. This same network of channels routes overbank floodwater to riverine wetlands during the early stages of overbank flooding.

This variable is designed to indicate, at a relatively coarse level of resolution, when project impacts reduce or eliminate the surface water connection between the riverine wetland and the adjacent stream channel. Fill projects, levee construction, and sidecast dredging are typical project impacts that reduce or eliminate these surface water connections, and as a result reduce the export of organic carbon. The percentage of the linear distance of stream reach that has been altered is used to quantify this variable. Measure it with the following procedure:

(1) Conduct a visual reconnaissance of the area being assessed and the adjacent stream reach. Estimate the percentage of this stream reach that has been modified with levees, sidecast materials, or other obstructions that reduce the exchange of surface water between the riverine wetland being assessed and the stream channel.

(2) Report the percent of the linear distance of the stream reach that has been altered.

In west-central peninsular Florida reference wetlands, the percentage of the linear distance of stream reach that has been altered ranged from 0 to 100 percent (Appendix D). Based on the range of values from reference standard sites, a variable subindex of 1.0 is assigned when surface connections are unaltered (Figure 29). A variable subindex of 1.0 is assigned when zero percent of the stream reach is altered. As the percentage of the stream reach that is altered increases, a subindex decreasing to zero at 100 percent alteration is assigned. This is based on the assumption that the relationship between surface water connections and organic carbon export is linear.

O Horizon Biomass (V_{OHOR}). This variable represents the total mass of organic matter in the O horizon. The O horizon is defined as the soil layer dominated by organic material that consists of recognizable or partially to

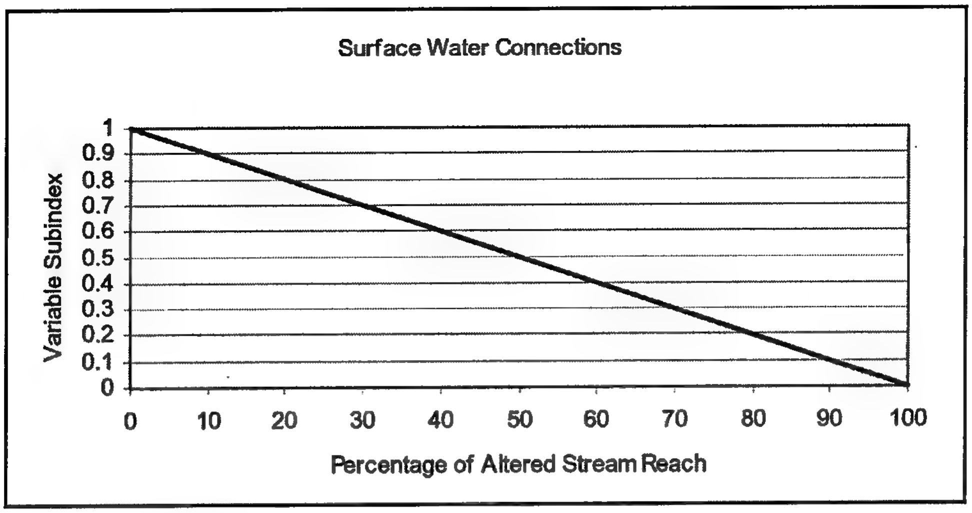

Figure 29. Relationship between surface water connections and functional capacity

highly decomposed organic matter such as leaves, needles, sticks, or twigs <0.6 cm in diameter, flowers, fruits, insect frass, moss, or lichens on or near the surface of the ground (USDA SCS 1993). The O horizon is synonymous with the terms detritus or litter layer used by other disciplines. In the context of this function the O horizon represents organic carbon available for export.

Percent cover of the O soil horizon is used to quantify this variable. The procedure for measuring it is described under Function 3.

In west-central peninsular Florida reference wetlands, percent O horizon measured 100 percent (Appendix D). Based on data from reference standard sites, a variable subindex of 1.0 is assigned when the O soil horizon is 100 percent (Figure 30). As O horizon cover decreases, a subindex linearly

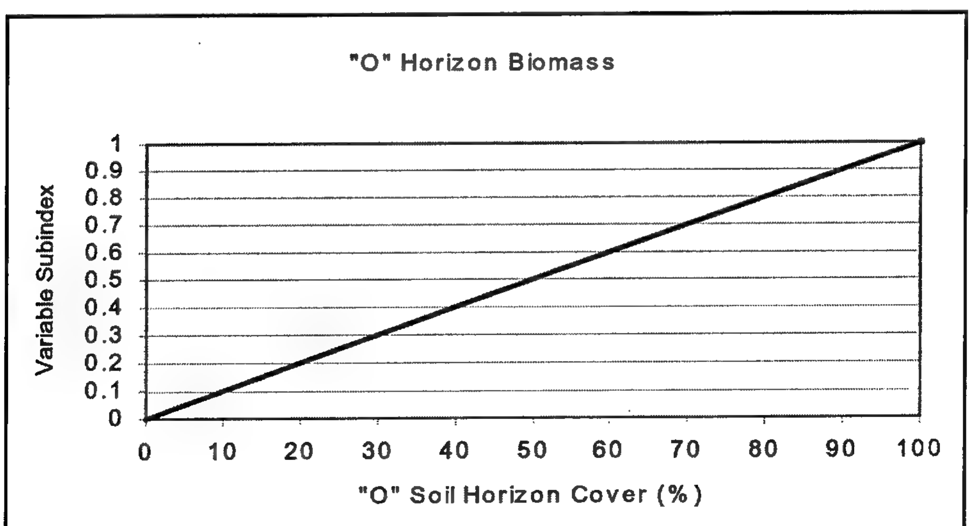

Figure 30. Relationship between soil O horizon biomass and functional capacity

decreasing to zero at zero percent cover is assigned. The rate at which the subindex decreases, and the selection of zero as the subindex at zero percent cover are based on the assumption that the relationship between O soil horizon cover and organic carbon export is linear, and that a decreasing amount of biomass in the tree, sapling, shrub, and ground vegetation strata of the plant community is reflected in lower percent O soil horizon cover. When percent O soil horizon declines to zero, organic carbon export has essentially ceased. These assumptions could be validated using the independent, quantitative measures of function defined previously.

Woody Debris Biomass (V_{WD}). This variable represents the total mass of organic matter contained in woody debris on or near the surface of the ground. Woody debris is defined as down and dead woody stems ≥0.25 in. (6 mm) in diameter that are no longer attached to living plants. Despite its relatively slow turnover rate, woody debris is an important component of food webs and nutrient cycles of temperate terrestrial forests (Harmon, Franklin, and Swanson 1986), and in the context of this function accounts for the contribution woody debris makes to exported organic carbon.

Volume of woody debris per hectare is used to quantify this variable. The procedure for measuring it is described under Function 3.

In west-central peninsular Florida reference wetlands, the volume of woody debris ranged from 0 to 304 m^3/ha (Appendix D). Based on data from reference standard sites, a variable subindex of 1.0 is assigned to sites with woody debris between 60 and 150 m^3/ha (Figure 31). Below 60 m^3/ha the subindex decreases linearly to zero. This range of values included reference sites that had been converted to agriculture and had little or no woody debris, sites in early stages of succession with low volumes of woody debris, and sites in the middle stages of succession with a volume of woody debris between 4 and 56 m^3/ha. The decrease in the variable subindex is based on the assumption that lower volumes of woody debris indicate an inadequate reservoir of organic carbon and an inability to

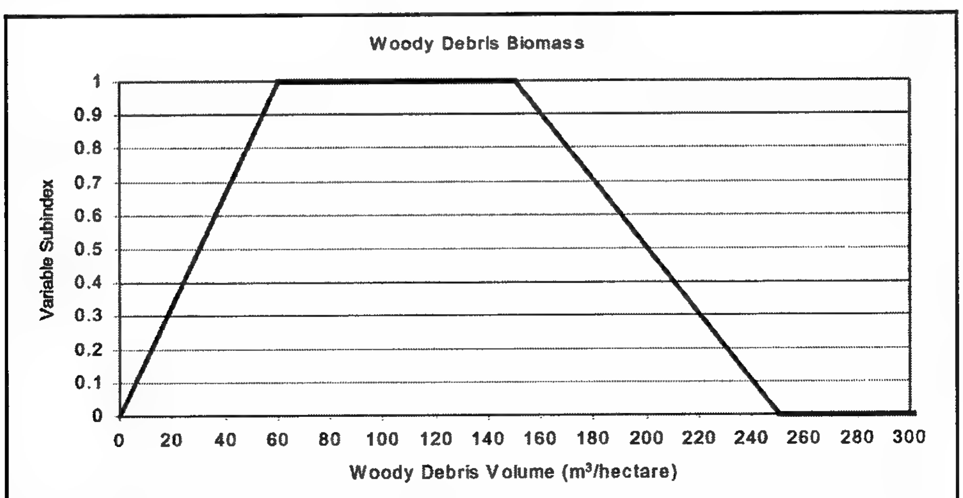

Figure 31. Relationship between woody debris biomass and functional capacity

contribute to organic carbon export. Above 150 m^3/ha the subindex decreases linearly to zero at 250 m^3/ha. This is based on the assumption that increasingly higher volumes of woody debris that result from logging will result in abnormally high levels of carbon.

Functional Capacity Index

The assessment model for calculating the FCI for Exportation of Organic Carbon is as follows:

$$FCI = \left[\left(V_{FREQ} \times V_{SURFCON} \right)^{1/2} \times \left(\frac{V_{OHOR} + V_{WD}}{2} \right) \right]^{1/2} \tag{15}$$

In the first part of this model the variables V_{FREQ} and $V_{SURFCON}$ reflect whether the mechanisms for exporting organic carbon from the riverine wetland are in place. The two variables are averaged by taking the geometric mean because without flooding, or surface water connections to the channel, organic carbon export could be reduced significantly or cease.

In the second subpart of the equation, the two important sources of dissolved and particulate organic carbon, V_{OHOR} and V_{WD}, are averaged by taking the geometric mean because either subpart is independently capable of significantly reducing the amount of carbon being exported. If the organic matter source is not present, carbon export will not occur. Similarly, if the transport vector is absent, carbon export will decrease or cease.

Function 7: Maintain Characteristic Plant Community

Definition

This function is defined as the capacity of a riverine wetland to provide the environment necessary for a characteristic plant community to develop and be maintained. In assessing this function one must consider both the extant plant community as an indication of current conditions, and the physical factors that determine whether or not a characteristic plant community is likely to be maintained in the future. Vegetation description and statistical analysis used to define and measure the associations between both the environmental and biotic factors are multifaceted. Arranging vegetation samples to determine the relationship of species in terms of composition and environmental gradients can be accomplished through ordination methods (Kent and Coker 1995). There are many ordination methods that can be used here. Some of these include the community classification method by TWINSPAN, an ordered two-way indicator species analysis (Hill 1979); detrended correspondence and reciprocal averaging of the DECORANA

method (Hill and Gauch 1980); or canonical correspondence (CANOCO), an analysis that integrates and scores both species and environmental data (ter Braak 1994). Plants exhibit various degrees of habitat fidelity in response to their adaptive tolerance to disturbance. One method for measuring vegetation patterns as a reliable site indicator of community composition is the Floristic Quality Assessment (FQA) (Taft et al. 1997).

Rationale for selecting the function

The ability to maintain a characteristic plant community is important because of the intrinsic value of the plant community and the many attributes and processes of riverine wetlands that are influenced by the plant community. For example, the unique physical environment of riverine wetlands due to periodic flooding contributes to higher productivity and nutrient cycling. Brinson et al. (1981) have determined that periodic flooding favors increased productivity of this specially adapted plant community. The pulsing flows provide an adequate water supply for vegetation and waste products are flushed while anaerobic root zones are oxygenated. Both allochthonous and autochthonous nutrients favorably alter soil chemistry to promote biogeochemical processes through periodic flooding. In addition, the plant community of a riverine wetland influences the quality of the physical habitat and biological diversity of adjacent rivers by modifying the quantity and quality of water (Gosselink, Lee, and Muir 1990) and through the export of carbon (Mitsch and Gosselink 1993; Wharton et al. 1982). The complexity of forested vegetation in this riverine wetland type provides the structure to dramatically reduce flood flow velocity and also facilitates a high species diversity of dependent terrestrial and aquatic fauna (Estevez, Dixon, and Flannery 1991; Wharton et al. 1982).

Characteristics and processes that influence the function

A variety of physical and biological factors determine the ability of a riverine wetland to maintain a characteristic plant community. Often, changes in hydrologic regime are not reflected in the community composition and structure for many years or even decades. Woody vegetation responds slowly to surface water drawdowns, diking, channelized streams, and other hydrologic impacts. Changes such as these affect wetland functional capacity and may not be readily apparent in vegetation structure and composition. Herbaceous species alone as an indicator of functional capacity may not accurately reflect current conditions as this community type responds quickly to both natural temporary cycles of drought and overbank scouring and to more permanent changes resulting from anthropogenic alteration.

Some field indicators that reflect hydrologic changes include abnormal root exposure and a high percentage of falling or leaning trees from oxidized soils that have reduced soil structure and consistency and may appear spongy. Plant indicators of hydrologic change can include an invasion of

opportunistic, upland bay trees, or exotic species that usually increase spatially with time. The changes reflected by these alterations are seen over time and must be interpreted carefully and synergistically. These changes are a result of diminished or altered wetland soils usually accompanied by diminishing hydrologic conditions. Hydrologic alteration influences soil structure and subsequently the native plant community.

A common problem associated with using field indicators to measure functional capacity is seasonal variation among biotic and abiotic components of the forested wetland. Often, the apparent status of a bottomland hardwood is not always revealed in a single visit. For example, riverine wetlands experience seasonal water table fluctuations, and consequently the soil surface may be dry. This can be misinterpreted as a hydrologic alteration. Many mature wetland trees have swollen and exposed roots containing gas-exchanging aerenchyma tissue that has evolved as an adaptive response to anaerobic conditions. This root exposure can be misinterpreted as soil subsidence. Thus, environmental indicators and single variables or factors may not provide an accurate reflection of the capacity of a wetland to perform this function. For these reasons, this function is assessed using variables that reflect both the composition and structure of the extant plant community, and abiotic factors that influence the capacity of a riverine wetland to maintain a characteristic plant community.

Description of model variables

Tree Biomass (V_{TBA}). Trees are defined as woody stems ≥6 m in height and ≥10 cm dbh. Diameter is by convention measured at 1.3 m above ground level and can be easily converted to basal area. Basal area is closely related to stand development and maturity (Brower and Zar 1984), and represents the simplest form of forest stand characterization. Basal area is the area occupied by the tree stems and represents the mass of organic material per unit area in the tree stratum. In the context of this function tree basal area 10 cm serves as an indicator of plant community structure and forest maturity. Tree basal area, a common measure of abundance and dominance in forest ecology has been shown to be proportional to tree biomass (Whittaker 1975; Whittaker et al. 1974; Spurr and Barnes 1981; Tritton and Hornbeck 1982; Bonham 1989) is used to quantify this variable. Measure tree biomass in basal area using the procedures described under Function 3.

In west-central peninsular Florida reference wetlands, tree basal area ranged from 0 to 73 m^2/ha (Appendix D). Based on the data from reference standard sites supporting mature and fully stocked forests, a variable subindex of 1.0 is assigned when basal area is ≥30 m^2/ha (Figure 32). At reference sites that have been cleared or are in middle to early successional stages, tree basal area is less; consequently a subindex linearly decreasing to zero at zero basal area is assigned. This is based on the assumption that the relationship between tree basal area and the capacity of the riverine wetland to maintain a characteristic plant community is linear. This assumption could

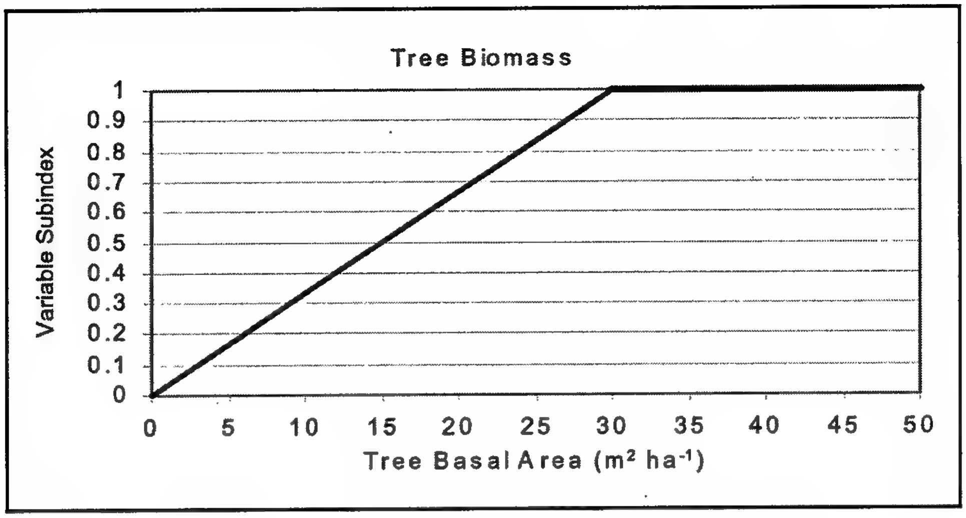

Figure 32. Relationship between tree biomass and functional capacity

be validated with data from a variety of low-gradient riverine wetlands in the southeast summarized by Clewell, Goolsby, and Shuey (1982); Leitman, Sohm, and Franklin (1983); Brinson (1990); Sharitz and Mitsch (1993); and Messina and Conner (1997), or the independent, quantitative measures of the function identified previously.

Understory Vegetation Biomass (V_{SSD}). This variable represents the number of shrubs and saplings per unit area in riverine wetlands. Shrubs and saplings are defined as woody stems >1 m in height and <10 cm dbh. Shrub and sapling stem density is inversely related to basal area in mature riverine forests. That is, as tree basal area increases with maturity, shrub and sapling density decreases. Therefore, shrub and sapling density can serve as an indicator of plant community structure. Measure shrub and sapling density using the procedures described under Function 3.

In west-central peninsular Florida reference wetlands, understory vegetation stem density ranged from 0 to nearly 5,500 stems/ha (Appendix D). Based on data from reference standard sites, a variable subindex of 1.0 is assigned when understory vegetation stem density is between 275 and 1,700 stems/ha (Figure 33). As understory stem density decreases, a subindex linearly decreasing to zero at zero stems/ha is assigned. This is based on the assumption that if understory vegetation does not exist, it does not contribute to nutrient cycling. As understory vegetation stem density increases above 1,700 stems/ha, a linearly decreasing subindex is assigned down to 0.5 at 1,900 stems/ha. Above 1,900 stems/ha a subindex of 0.5 is assigned. The rationale for this is that it is common for understory stem density to exceed 500 stems/ha during the middle stages of succession (Whittaker 1975). As the forest matures, competition for resources results in a decrease in understory stem density to the levels observed at reference standard sites. The rate at which the subindex increases, decreases, and levels out above 1,700 stems/ha represents an educated guess of the relationship between understory stem densities and nutrient cycling. These assumptions could be validated using the data from a variety of low-gradient riverine wetlands in

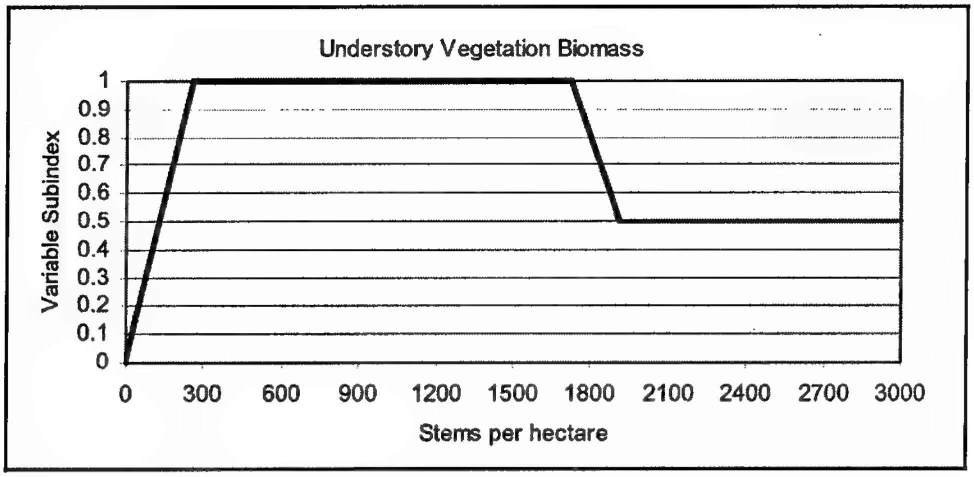

Figure 33. Relationship between understory vegetation biomass and functional capacity

the southeast summarized by Brinson (1990), Christensen (1991), Sharitz and Mitsch (1993), and Messina and Conner (1997), or by the independent, quantitative measures of function identified previously.

Overstory and Understory Species Composition (V_{OUS}). Plant species composition represents the diversity of plants in riverine wetlands. Healthy, mature riverine forests in peninsular Florida support high species diversity in all strata. A possible combination of up to 12 different species of trees from a list of 30 trees can occur without dominance in one reference standard site. This heterogeneity of species diversity is a common feature within bottomland hardwoods in peninsular Florida. A mature forest with characteristic plant species will support the greatest diversity of characteristic wildlife. Wildlife habitat values are directly dependent on a diverse native plant composition. Nonindigenous invasive exotics can severely threaten the integrity of a natural plant community. Infestation can directly reduce or eliminate plant diversity by growing quickly and overshadowing natives or by allelopathic competition. Indirectly, invasive exotics can reduce, eliminate, or change species composition by altering water tables, modifying nutrient cycles, and modifying edaphics. Exotics are highly adaptable and have the ability to establish quickly in both disturbed and undisturbed habitats, producing copious seeds or spores that possess numerous methods for dispersing to new locations. Australian pine (*Casuarina* spp.) can grow at a rate of 15 ft (5 m) per year and produces up to 10,000 seeds annually (Jensen and Vosick 1994). Skunk vine (*Paederia foetida*) and air potato (*Dioscorea bulbifera*) quickly expand over all vegetative strata directly causing the death of natives (Schmitz 1994). The thick twining mats of Old World climbing fern (*Lygodium microphyllum*) have been spreading throughout Florida and can shade out understory natives, reducing diversity. Although acres of infestation by numerous species has been estimated (Florida Department of Environmental Protection 1994), direct studies determining growth rates of individual species are low; and research in this area is needed. To compensate for the absence, the Florida Exotic Pest Plant Council (EPPC) has categorized most of the invasives

according to their potential to invade and disrupt native plant communities, and their list will be used here (Florida Exotic Pest Plant Council 2001). In the context of this function, the presence of exotics facilitates a high and timely risk factor that can threaten the otherwise normal functional capacity of a native plant community. Thus, this variable accounts for the potential threat imposed by invasive exotics on the existing native plant community. Therefore, characteristically diverse native bottomland plant species composition should be expected to provide habitat necessary for bottomland forest wildlife species.

Plants exhibit various degrees of habitat fidelity in response to their adaptive tolerance to disturbance. Each species responds differently to varying combinations and degrees of disturbance frequency, duration, and intensity resulting in spatial compositional degradation. One method for measuring vegetation patterns as a reliable site indicator of community composition is the Floristic Auality Assessment (FQA) (Taft et al. 1997). The methodology behind the FQA is based on differentiating vegetation by species on the basis of individual fidelity to specific habitat type and native species diversity and richness.

Ideally, plant species composition would be determined with intensive sampling of woody and herbaceous species in all vegetative strata. Unfortunately, the time and taxonomic expertise required to accomplish this is not available in the context of rapid assessment. Thus the focus here is on all species in the canopy and understory strata. To allow greater sensitivity in interpretation of floristic integrity across the range of variation within an HGM subclass, quantitative data are needed. This may be required in HGM subclasses encompassing several seral stages or those subject to fluctuations in composition diversity or community structure based on intra- or interannual climatic cycles. Also, a ranking category with species having high coefficient of conservation (COC) values, described in the following subparagraph (3), at low abundance can result in sites having the same COC values but different Floristic Quality Indices (FQI's) or sites having the same FQI's but different COC values. The FQI's algorithm is provided in Appendix B. Measure overstory and understory community composition using the following procedure:

(1) Identify all species in the overstory and understory vegetative layers. Use tree basal area to determine abundance in the overstory stratum (see discussion of "Tree Biomass (V_{TDBH})" variable under Function 3 for methods) and use density to determine abundance in the understory stratum (see discussion of "Understory Vegetation Biomass (V_{SSD})" variable under Function 3 for methods). Sampling during the dormant season may require a high degree of proficiency in identifying tree bark or dead plant parts. Users who do not feel confident in identifying plant species in all strata should get help with plant identification.

(2) Table 11 provides species ranking for the overstory and understory vegetation strata. (Species identified at the site but not occurring on

Table 11
Species by Strata Occurring in West-Central Peninsular Florida Low-Gradient Riverine Wetlands

Species Number	Species	Common Name	COC
Overstory Species			
1	*Acer rubrum*	Red maple	4
2	*Carpinus caroliniana*	American hornbean/Muscle wood	5
3	*Carya aquatica*	Water hickory	5
4	*Carya glabra*	Sweet hickory	5
5	*Celtis laevigata*	Sugarberry	4
6	*Citrus* sp.	Wild citrus	2
7	*Cornus foemina*	Swamp dogwood	5
8	*Diospyros virginiana*	Common persimmon	5
9	*Fraxinus caroliniana*	Carolina ash/Pop ash	5
10	*Gleditsia aquatica*	Water locust	5
11	*Gordonia lasianthus*	Loblolly bay	4
12	*Ilex opaca*	American holly	5
13	*Juniperus silicicola*	Red cedar	4
14	*Liauidambar styraciflua*	Sweet gum	5
15	*Magnolia virginiana*	Sweet bay	5
16	*Morus rubra*	Red mulberry	5
17	*Nyssa biflora*	Water tupelo	5
18	*Persea palustris*	Swamp bay	5
19	*Prunus serotina*	Cherry laurel	2
20	*Quercus laurifolia*	Laurel oak	5
21	*Quercus nigra*	Water oak	5
22	*Quercus virginiana*	Live oak	5
23	*Schinus terebinthifolius*	Brazilian pepper	1
24	*Taxodium distichum*	Bald cypress	5
25	*Tilia americana*	Basswood	5
26	*Ulmus americana*	American elm	5
Understory Species			
1	*Acer rubrum*	Red maple	4
2	*Bumelia reclinata*	Florida Bumelia	5
3	*Carpinus caroliniana*	American hornbean/Muscle wood	5
4	*Carya aquatica*	Water hickory	5
5	*Carya glabra*	Sweet hickory	5
6	*Celtis laevigata*	Sugarberry	4

(Sheet 1 of 5)

Table 11 (Continued)			
Species Number	Species	Common Name	COC
	Understory Species (Continued)		
7	*Cephalanthus occidentalis*	Button bush	5
8	*Citrus* sp.	Wild citrus	2
9	*Cornus foemina*	Swamp dogwood	5
10	*Crataegus marshallii*	Parsley haw	5
11	*Diospyros virginiana*	Common persimmon	5
12	*Fraxinus caroliniana*	Carolina ash/Pop ash	5
13	*Gleditsia aquatica*	Water locust	5
14	*Gordonia lasianthus*	Loblolly bay	4
15	*Ilex cassine*	Dahoon holly	5
16	*Ilex opaca*	American holly	5
17	*Itea virginica*	Virginia willow	5
18	*Juniperus silicicola*	Red cedar	4
19	*Liguidambar styraciflua*	Sweet gum	5
20	*Magnolia virginiana*	Sweet bay	5
21	*Morus rubra*	Red mulberry	5
22	*Myrica cerifera*	Wax myrtle	3
23	*Nyssa biflora*	Water tupelo	5
24	*Persea palustris*	Swamp bay	5
25	*Prunus serotina*	Cherry laurel	2
26	*Quercus laurifolia*	Laurel oak	5
27	*Quercus nigra*	Water oak	5
28	*Quercus virginiana*	Live oak	5
29	*Sabal minor*	Dwarf palmetto	5
30	*Sabal palmetto*	Cabbage palm	4
31	*Salix caroliniana*	Carolina willow	2
32	*Schinus terebinthifolius*	Brazilian pepper	1
33	*Serenoa repens*	Saw palmetto	3
34	*Taxodium distichum*	Bald cypress	5
35	*Tilia americana*	Basswood	5
36	*Ulmus americana*	American elm	5
37	*Vaccinium arboreum*	Farkleberry/Sparkleberry	4
38	*Vaccinum corymbosum*	Highbush blueberry	4
39	*Viburnum obovatum*	Walter viburnum	5
			(Sheet 2 of 5)

Table 11 (Continued)

Species Number	Species	Common Name
	Dominant Ground Cover Species	
1	*Ampelopsis arborea*	Pepper-vine
2	*Arisaema triphyllum*	Swamp jack-in-the-pulpit
3	*Asclepius perennis*	Aquatic milkweed
4	*Aster carolinianus*	Climbing aster
5	*Aster elliottii*	Elliott's aster
6	*Bacopa monnieri*	Coastal water-hyssop
7	*Blechnum serrulatum*	Swamp fern
8	*Boehmeria cylindrica*	Small-spike false-nettle
9	*Campsis radicans*	Trumpet-creeper
10	*Carex elliottii*	Elliott's sedge
11	*Carex gigantea*	Large sedge
12	*Carex longii*	Greenish-white sedge
13	*Carex lupuliformis*	False hop sedge
14	*Carex typhina*	Cat-tail sedge
15	*Carpinus caroliniana*	American hornbeam
16	*Chasmanthium nitidum*	Shiny spikegrass
17	*Clematis crispa*	Swamp virgin's-bower
18	*Commelina diffusa*	Spreading dayflower
19	*Conoclinium coelestinum*	Mistflower
20	*Crinum americanum*	Southern swamplily
21	*Dichanthelium ensifolium*	
22	*Dichondra caroliniensis*	Pony-foot
23	*Dyschoriste humistrata*	Swamp dyschoriste
24	*Elytraria caroliniensis*	Carolina scaly-stem
25	*Epidendrum conopseum*	
26	*Erechtites hieracifolia*	Fireweed
27	*Habeneria repens*	Rein orchid
28	*Hydrocotyl umbellata*	Many-flower penny-wort
29	*Hymenocallis* spp.	Spider-Lily
30	*Hypericum hypericoides*	St. Andrew's cross
31	*Hypoxis leptocarpa*	Yellow stargrass
32	*Iris virginica*	Virginia blueflag
33	*Lactuca floridana*	Woodland lettuce
34	*Ludwigia repens*	Creeping seedbox
35	*Lycopus rubellus*	Taper-leaf bugleweed
36	*Mecardonia acuminata*	Purple mecardonia
37	*Mitchella repens*	Partridge-berry
38	*Oplismenus setarius*	Basket grass
39	*Orontium aquaticum*	Golden club
		(Sheet 3 of 5)

Table 11 (Continued)

Species Number	Species	Common Name
	Dominant Ground Cover Species (Continued)	
40	*Osmunda cinnamomea*	Cinnamon fern
41	*Osmunda regalis*	Royal fern
42	*Oxalis corniculata*	Creeping woodsorrel
43	*Panicum commutatum*	Variable witchgrass
44	*Panicum dichotomiflorum*	Fall panic grass
45	*Panicum dichotomum*	Cypress witchgrass
46	*Panicum gymnocarpon*	Savannah panic grass
47	*Panicum rigidulum*	Red-top panic grass
48	*Parietaria floridana*	Florida pellitory
49	*Parthenocissus quinquefolia*	Virginia creeper
50	*Phanopyrum gymnocarpon*	Savannah panic grass
51	*Physostegia leptophylla*	Slender-leaf dragon-head
52	*Physotegia purpea*	Purple dragon-head
53	*Pluchea foetida*	Stinking camphor-weed
54	*Pluchea odorata*	Shrubby camphor-weed
55	*Polygonum setaceum*	
56	*Psychotria nervosa*	Shiny wild coffee
57	*Psychotria sulzneri*	Dull wild coffee
58	*Rhus copallinum*	Winged sumac
59	*Rhynchospora caduca*	Falling beakrush
60	*Rhynchospora miliacea*	Millet beakrush
61	*Rhynchospora* spp.	
62	*Ruellia caroliniensis*	Wild-petunia
63	*Sabatia calycina*	Coast rose-gentian
64	*Samolus parviflorus*	Water pimpernel
65	*Saururus cernuus*	Lizard's tail
66	*Senecio anonymus*	Small's groundsel
67	*Senecio glabellus*	Butterweed
68	*Smilax bona-nox*	Saw greenbrier
69	*Smilax laurifolia*	
70	*Thelypteris dentata*	Downy maiden fern
71	*Thelypteris hispidula*	Hairy tri-vein fern
72	*Thelypteris interrupta*	Willdenow's maiden fern
73	*Thelypteris palustris*	Marsh fern

(Sheet 4 of 5)

Table 11 (Concluded)		
Sp#ecies Number	Tree Species	Common Name
Dominant Ground Cover Species (Continued)		
74	*Toxicodendron radicans*	Poison ivy
75	*Viola affinis*	Leconte's violet
76	*Vitis munsoniana*	Muscadine grape
77	*Woodwardia aereolata*	Netted chainfern
78	*Woodwardia virginica*	Virginia chainfern
		(Sheet 5 of 5)

this list can be added and ranked after consulting floristic manuals or publications along with confirmation by experienced ecologists or botanists.) Exotic species are listed in Table 12.

(3) Calculate the FQI using the automated sheet or by the following explanation using the equations provided in Appendix B. A ranking from 1-5 has been assigned to each species in Tables 11 and 12. The rank of 5 has been assigned to species having the highest fidelity to bottomland hardwood forests. Lower ranks have been assigned to species having lower fidelity to bottomland hardwood forests with the tendency to occur in many habitat types to those species that are invasive. This index is termed the coefficient of conservation (COC). Following are the categories for overstory and understory species rankings:

Ranking	Description
1	Taxa that are adapted to severe disturbance, in particular anthropogenic and all invasive exotic species, generally considered ruderal-invasive species.
2	Taxa associated with more stable though degraded habitat, generally considered ruderal-competitive nuisance species.
3	Taxa having a high consistency of occurrence within several community types that can persist under moderate disturbance. Increases in the intensity and frequency of disturbance may result in an increase in population size.
4	Taxa associated mostly with natural areas but can persist where habitat has been somewhat altered or degraded. Increases in the intensity or frequency of disturbance may result in reduced population size, may be

Table 12
Florida Exotic Pest Plant Council's List of Florida's Most Invasive Species

Scientific Name	Common Name	FLEPPC Rank	Government Listed	COC Rank
Category I – Species that are invading and disrupting native plant communities in Florida. *This definition does not rely on the economic severity or geographic range of the problem, but on the documented ecological damage caused.*				
Abrus precatorius	Rosary pea	I		1
Acacia auriculiformis	Earleaf acacia	I		1
Albizia julibrissin	Mimosa, silk tree	I		1
Albizia lebbeck	Woman's tongue	I		1
Ardisia crenata (=*A. crenulata*)	Coral ardisia	I		1
Ardisia elliptica (=*A. humilis*)	Shoebutton ardisia	I		1
Asparagus densiflorus	Asparagus-fern	I		1
Bauhinia variegata	Orchid tree	I		1
Bischofia javanica	Bischofia	I		1
Calophyllum antillanum (=*C. calaba; C. inophyllum*, often misapplied in cultivation)	Santa maria (names "mast wood," "Alexandrian laurel" used in cultivation)	I		1
Casuarina equisetifolia	Australian pine	I	P	1
Casuarina glauca	Suckering Australian pine	I	P	1
Cestrum diurnum	Day jessamine	I		1
Cinnamomum camphora	Camphor-tree	I		1
Colocasia esculenta	Wild taro	I		1
Colubrina asiatica	Lather leaf	I		1
Cupaniopsis anacardioides	Carrotwood	I	N	1
Dioscorea alata	Winged yam	I	N	1
Dioscorea bulbifera	Air-potato	I	N	1
Eichhornia crassipes	Water-hyacinth	I	P	1
Eugenia uniflora	Surinam cherry	I		1
Ficus microcarpa (*F. nitida* and *F. retusa* var. *nitida* misapplied)	Laurel fig	I		1
Hydrilla verticillata	Hydrilla	I	P, N	1
Hygrophila polysperma	Green hygro	I	P, N	1
Hymenachne amplexicaulis	West Indian marsh grass	I		1
Imperata cylindrica (*Imperata brasiliensis* misapplied)	Cogon grass	I	N	1
Ipomoea aquatica	Waterspinach	I	P, N	1
Jasminum dichotomum	Gold Coast jasmine	I		1
Jasminum fluminense	Brazilian jasmine	I		1
Lantana camara	Lantana, shrub verbena	I		1
Ligustrum sinense	Chinese privet, hedge privet	I		1
Lonicera japonica	Japanese honeysuckle	I		1

(Sheet 1 of 4)

Table 12 (Continued)

Scientific Name	Common Name	FLEPPC Rank	Government Listed	COC Rank
Category I (Continued)				
Lygodium microphyllum	Old World climbing fern	I	N	1
Macfadyena unguis-cati	Cat's claw vine	I		1
Melaleuca quinquenervia	Melaleuca, paper bark	I	P, N	1
Melia azedarach	Chinaberry	I		1
Mimosa pigra	Catclaw mimosa	I	P, N	1
Nandina domestica	Nandina, heavenly bamboo	I		1
Nephrolepis cordifolia	Sword fern	I		1
Nephrolepis multiflora	Asian sword fern	I		1
Neyraudia reynaudiana	Burma reed; cane grass	I	N	1
Paederia cruddasiana	Sewer vine, onion vine	I	N	1
Paederia foetida	Skunk vine	I	N	1
Panicum repens	Torpedo grass	I		1
Pennisetum purpureum	Napier grass	I		1
Pistia stratiotes	Water lettuce	I	P	1
Psidium cattleianum (=*P. littorale*)	Strawberry guava	I		1
Psidium guajava	Guava	I		1
Pueraria montana (=*P. lobata*)	Kudzu	I	N	1
Rhodomyrtus tomentosa	Downy rose-myrtle	I	N	1
Rhoeo spathacea (=*R. discolor; Tradescantia spathacea*)	Oyster plant	I		1
Sapium sebiferum	Popcorn tree, Chinese tallow tree	I	N	1
Scaevola sericea (=*Scaevola taccada* var. *sericea, S. frutescens*)	Scaevola, half-flower, beach naupaka	I		1
Schefflera actinophylla (=*Brassaia actinophylla*)	Schefflera, Queensland umbrella tree	I		1
Schinus terebinthifolius	Brazilian pepper	I	P, N	1
Senna pendula (=*Cassia coluteoides*)	Climbing cassia, Christmas cassia, Christmas senna	I		1
Solanum tampicense (=*S. houstonii*)	Wetland night shade, aquatic soda apple	I	N	1
Solanum torvum	Susumber, turkey berry	I	N	1
Solanum viarum	Tropical soda apple	I	N	1
Syzygium cumini	Jambolan, Java plum	I		1
Tectaria incisa	Incised halberd fern	I		1
Thespesia populnea	Seaside mahoe	I		1
Tradescantia fluminensis	White-flowered wandering jew	I		1
Urochloa mutica (=*Brachiaria mutica*)	Pará grass	I		1

(Sheet 2 of 4)

Table 12 (Continued)				
Scientific Name	**Common Name**	**FLEPPC Rank**	**Government Listed**	**COC Rank**
Category II – Species that have shown a potential to disrupt native plant communities. These species may become ranked as Category I, but have not yet demonstrated disruption of natural Florida communities.				
Adenanthera pavonina	Red sandalwood	II		1
Agave sisalana	Sisal hemp	II		1
Aleurites fordii	Tung oil tree	II		1
Alstonia macrophylla	Devil-tree	II		1
Alternanthera philoxeroides	Alligator weed	II	P	1
Anredera leptostachya	Madeira vine	II		1
Antigonon leptopus	Coral vine	II		1
Aristolochia littoralis	Calico flower	II		1
Asystasia gangetica	Ganges primrose	II		1
Begonia cucullata	Begonia	II		1
Broussonetia papyrifera	Paper mulberry	II		1
Callisia fragrans	Inch plant, spironema	II		1
Casuarina cunninghamiana	Australian pine	II	P	1
Cereus undatus (=*Hylocereus undatus*)	Night-blooming cereus	II		1
Clerodendrum bungei	Strong-scented glorybower	II		1
Cryptostegia madagascariensis	Rubber vine	II		1
Cyperus alternifolius (=*C. involucratus*)	Umbrella plant	II		1
Cyperus prolifer	Dwarf papyrus	II		1
Dalbergia sissoo	Indian rosewood, sissoo	II		1
Eleagnus pungens	Thorny eleagnus	II		1
Enterolobium contortisiliquum	Ear-pod tree	II		1
Epipremnum pinnatum cv. Aureum	Pothos	II		1
Ficus altissima	False banyan	II		1
Flacourtia indica	Governor's plum	II		1
Flueggea virosa	Chinese waterberry	II		1
Hibiscus tiliaceus	Mahoe, sea hibiscus	II		1
Hiptage benghalensis	Hiptage	II		1
Jasminum sambac	Arabian jasmine	II		1
Koelreuteria elegans	Golden rain tree	II		1
Leucaena leucocephala	Lead tree	II		1
Ligustrum lucidum	Glossy privet	II		1
Livistona chinensis	Chinese fan palm	II		1
				(Sheet 3 of 4)

Table 12 (Concluded)

Scientific Name	Common Name	FLEPPC Rank	Government Listed	COC Rank
Category II (Continued)				
Melinis minutiflora	Molasses grass	II		1
Merremia tuberosa	Wood-rose	II		1
Murraya paniculata	Orange-jessamine	II		1
Myriophyllum spicatum	Eurasian water-milfoil	II	P	1
Ochrosia parviflora (=O. elliptica)	Kopsia	II		1
Oeceoclades maculata	Ground orchid	II		1
Passiflora biflora	Twin-flowered passion vine	II		1
Passiflora foetida	Stinking passion-flower	II		1
Phoenix reclinata	Senegal date palm	II		1
Phyllostachys aurea	Golden bamboo	II		1
Pteris vittata	Chinese brake	II		1
Ptychosperma elegans	Solitary palm	II		1
Rhynchelytrum repens	Natal grass	II		1
Ricinus communis	Castor bean	II		1
Ruellia brittoniana (=R. tweediana)	Mexican petunia	II		1
Sansevieria hyacinthoides (=S. trifasciata)	Bowstring hemp	II		1
Sesbania punicea	Purple sesban, rattlebox	II		1
Solanum diphyllum	Twinleaf nightshade	II		1
Solanum jamaicense	Jamiaca nightshade	II		1
Syngonium podophyllum	Arrowhead vine	II		1
Syzygium jambos	Rose-apple	II		1
Terminalia catappa	Tropical almond	II		1
Tribulus cistoides	Puncture vine, burnut	II		1
Triphasia trifoliata	Lime berry	II		1
Urena lobata	Caesar's weed	II		1
Wedelia trilobata	Wedelia	II		1
Wisteria sinensis	Chinese wisteria	II		1
Xanthosoma sagittifolium	Melanga, elaphant ear	II		1

(Sheet 4 of 4)

	subject to local extirpation, or the population size of a taxon may highly increase.
5	Taxa exhibit a high degree of fidelity to a narrow range of synecological parameters. Species within this category are restricted to relatively intact natural areas.

(4) Using basal area for overstory and density for understory species, calculate the quantities for each species for each site.

(5) Sum the basal area or density for every species having the same COC category ranking (i.e., COC Ranks 1 through 5, combine the sum for all 1's, combine the sum for all 2's, etc.).

(6) Calculate the relative percentage of the basal area or density for each of the five COC categories based on the total percentage of basal area or density of all species for the site. A sum of the percentages should yield 100 percent.

(7) Multiply the percentage for each COC category ranking by the following factors:

COC Rank	Factor	Based on Reference Standards
1	0	Invasive exotics receive no value
2	0.1	
3	0.3	
4	0.8	If the percentage is <40 percent
	0.1	If the percentage is >40 percent
5	1.0	

(8) Sum the factorial COC category ranks for the total FQI for that layer. The overstory and understory vegetative layers can each receive a maximum score of 100 with a combined total score of 200. An example is provided in Appendix B.

(9) Report plant species composition for overstory and understory species (V_{OUS}) as a combined score.

In west-central peninsular Florida reference wetlands, the FQI based on overstory and understory vegetative layers ranged from 50 to 200 (Appendix D). Based on the data from reference standard sites supporting mature and fully stocked forests, a variable subindex of 1.0 is assigned when FQI scores range from 190 to 200. As the FQI index decreases, a linearly decreasing subindex is assigned down to zero at an index of zero (Figure 34). This is based on the assumption that the relationship between overstory and understory plant species composition and the capacity of the riverine wetland to maintain a characteristic plant community is linear.

Dominant Ground Cover Species Composition (V_{DGCS}). A dominance of native wetland ground cover species is also improtant for the same reasons as stated in the overstory and understory species composition variable. It is also possible that greater than 50 species of herbaceous

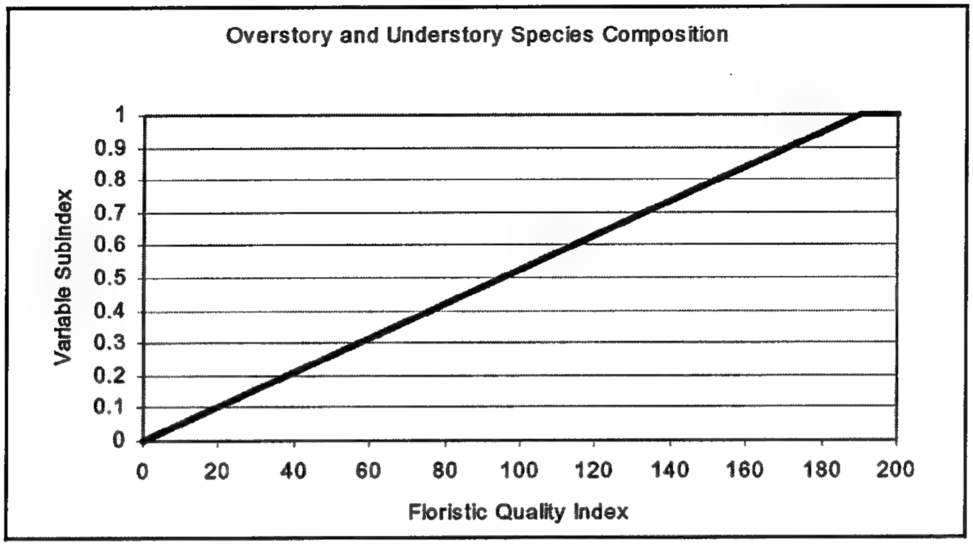

Figure 34. Relationship between overstory and understory species composition and functional capacity

plants from a list of 250 can occur in one references standard stie. This variable focuses only on dominant species in the ground cover strata. Use the following procedure to measure this variable:

(1) Identify the ground cover dominants from the area being assessed by summing the relative cover, as a measure of abundance, beginning with the most abundant species in descending order until at least 50 percent dominance is reached, including species with ≥10 percent relative abundance.

(2) Calculate percent concurrence by comparing the list of dominant ground cover species to the list of dominant species found in reference standard wetlands (Table 11). For example, if all the dominants from the area being assessed occur on the list of dominants from reference standard wetlands, then there is 100 percent concurrence. If three out of the five dominant ground cover species from the area being assessed occur on the list, then there is 60 percent concurrence. Exotic ground cover dominance does not receive a value. For example, if three out of six dominant ground cover species from the area being assessed occur on the list, and an additional dominant species is an exotic, then there is 50 percent concurrence: 3 + 0 = 3/6 = 50 percent.

(3) Report concurrence of ground cover species dominants as a percent.

In west-central peninsular Florida reference wetlands, concurrence with dominant ground cover species plant composition ranged from 0 to 100 percent (Appendix D). Based on the data from reference standard sites, a variable subindex of 1.0 was assigned when percent concurrence ranged from 90 to 100 percent. As the percentage of concurrence decreases, a linearly decreasing variable subindex is assigned down to zero at zero percent (Figure 35). This is based on the assumption that the relationship between

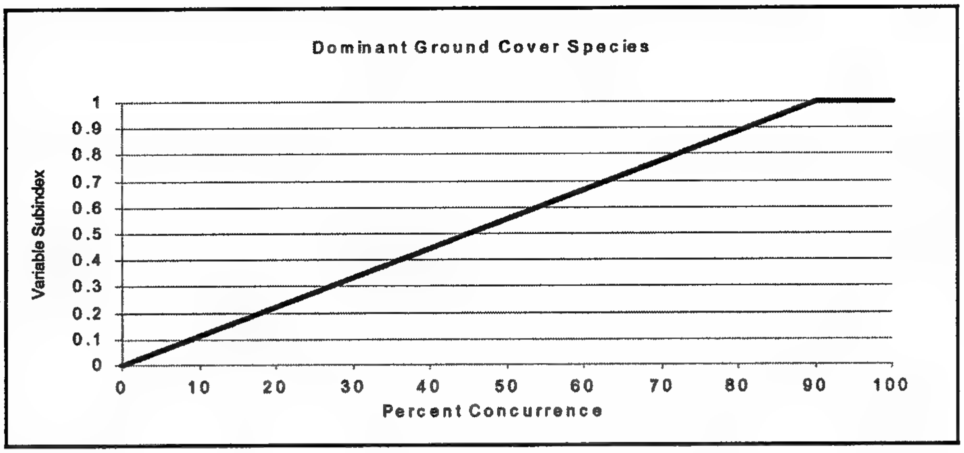

Figure 35. Relationship between dominant ground cover species composition and functional capacity

ground cover species composition and the capacity of the riverine wetland to maintain a characteristic plant community is linear.

Frequency of Overbank Flooding (V_{FREQ}). This variable represents the frequency at which water from a stream overtops its banks (i.e., exceeds channel-full discharge) and inundates riverine wetlands on the floodplain. Overbank flood frequency is the manifestation of current conditions in the watershed and channel at the spatial scale of the riverine wetland. In the context of this function, overbank flood frequency serves as an indication that a characteristic hydrologic regime to which the plant community is adapted is in place.

Recurrence intervals in years is used to quantify this variable. The procedure for measuring it is described under the model variables for Function 1.

In west-central peninsular Florida reference wetlands, using the regional curve or equations from the ratio or regression approach, the recurrence interval ranged from less than 1 to 100 years (Appendix D). Based on the range of values from reference standard sites, a variable subindex of 1.0 is assigned to recurrence intervals ≤3 years (Figure 36). Longer recurrence intervals are assigned a linearly decreasing subindex to 0.1 at a recurrence interval of 10 years. This is based on the assumption that where entrenchment, channelization, or levees effectively increase the depth of the stream channel, a greater discharge is required to overtop the bank and inundate the riverine wetland.

Since greater discharges occur less frequently, the volume of surface water that inundates riverine wetlands is less than what characteristically occurs at reference standard sites. The rationale for the rate at which the subindex drops to 0.1 (i.e., 1.0 to 0.1) is based on the assumption that as frequency increases, the inundation of the wetland by annual peak discharges decreases to one-tenth the frequency over a period of 10 years under reference standard conditions. Recurrence intervals >10 years are assigned a

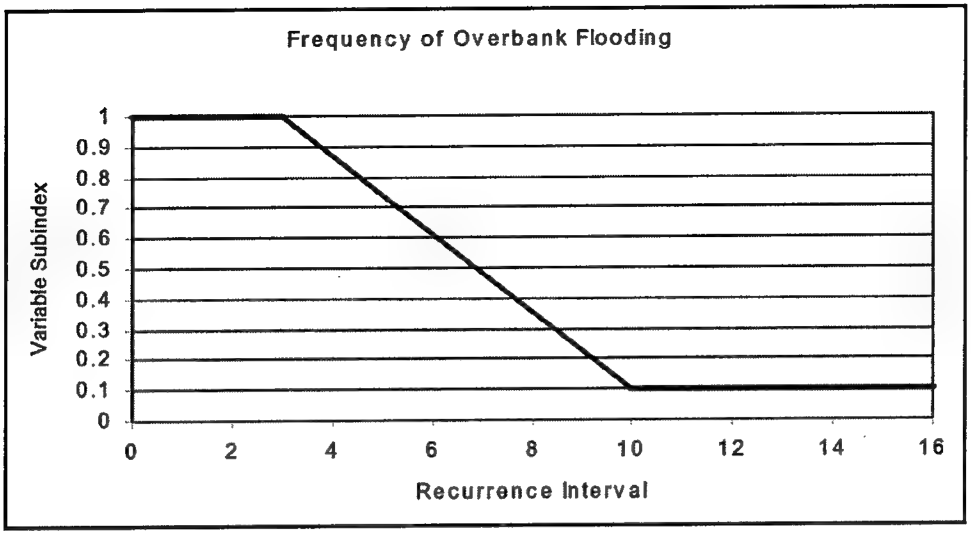

Figure 36. Relationship between frequency of overbank flooding and functional capacity

subindex of 0.1. This is based on the assumption that even at longer recurrence intervals, riverine wetlands do flood, albeit infrequently. Again, conceptual arguments can be made for dropping the subindex to 0, but it is difficult to determine at what point an increasing recurrence interval begins to significantly influence the ecological processes linked to overbank flooding.

Water Table Depth (V_{WTD}). This variable represents the depth to SHWT in the riverine wetland. In the context of this function, this variable indicates that plant communities adapted to the characteristic SHWT will develop and be maintained.

Depth to the SHWT is used to quantify this variable. The procedure for measuring this variable is described under Function 4.

In west-central peninsular Florida reference wetlands, the depth to SHWT ranged from 0 to 24 in. (0.6 m) below the surface (Appendix D). Based on the range of values from reference standard sites, a variable subindex of 1.0 was assigned to SHWT "depths" between 0 (i.e., ground surface) and 6 in. (0.15 m) below the ground (Figure 37). As the depth to the SHWT increases (i.e., is further below the surface of the ground) the subindex decreases linearly to 0 at a depth of 24 in. (0.6 m). This is based on the assumption that the capacity of the riverine wetland to maintain the degree of soil saturation required for characteristic biogeochemical processes and plant and animal communities is dependent on maintaining a characteristic high water table near or above the surface of the ground.

Soil Integrity ($V_{SOILINT}$). This variable is defined as the integrity of the soils within the area being assessed. Soil integrity is defined as the degree to which a soil approximates the natural undisturbed soil originally found at the site with respect to texture, structure, horizonation, organic

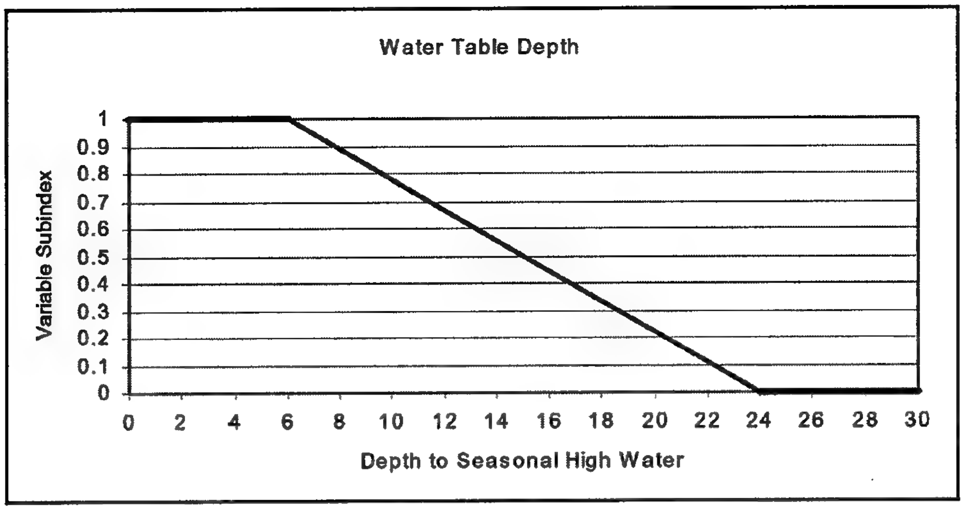

Figure 37. Relationship between water table depth and functional capacity

matter content, and biological activity. Soil is the medium on which the plant community develops and is maintained. Altering the properties of soil through anthropogenic activities (e.g., fill, excavation, plowing, compaction) or unnatural biological activities (e.g., pig rooting, cattle trampling or grazing) has the potential to affect the structure and composition of the plant community.

In a rapid assessment, it is difficult to assess soil integrity for two reasons. First, a variety of soil properties contribute to integrity that must be measured (i.e., structure, horizonation, texture, bulk density). Second, the spatial variability of soils within riverine wetlands makes it difficult to collect the number of samples necessary to adequately characterize a site. Therefore, the approach used here is to assume that soil integrity exists where evidence of alteration is lacking. In other words, if the soils in the assessment area do not exhibit any of the characteristics associated with alteration, it is assumed that soils are similar to those occurring in the reference standard wetlands and have the potential to support a characteristic plant community.

The field measure of this variable is the proportion of the assessment area with altered soils. Measure it with the following procedure:

(1) Determine if any of the soils in the area being assessed have been altered. In particular, look for alteration to a normal soil profile (for example, the absence of an A horizon).

(2) If no altered soils exist, assign the variable subindex a value of 1.0. This indicates that all of the soils in the assessment area are similar to soils in reference standard sites.

(3) If altered soils exist, determine what percent of the assessment area has soils that have been altered.

(4) Report the percent of the assessment area with altered soils.

In west-central peninsular Florida reference wetlands, the percent of area with altered soils ranged from zero to 100 (Appendix D). Based on the values from reference standard sites, a variable subindex of 1.0 was assigned when the percent of area with altered soils was zero (Figure 38). As the percentage of area with altered soils increases, a subindex linearly decreasing to zero at 100 percent alteration is assigned. This is based on the assumption that as the percentage of altered soils increases, the capacity of the soil to support a characteristic plant community decreases linearly.

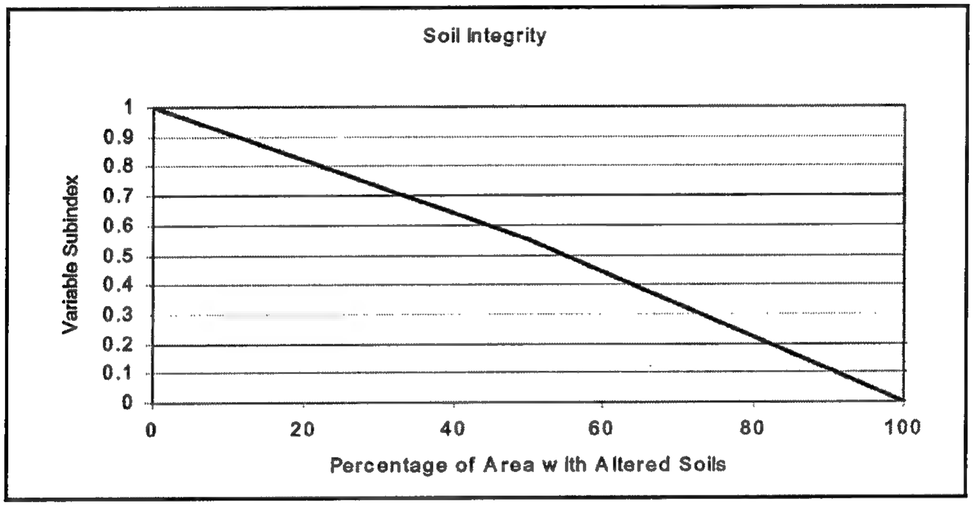

Figure 38. Relationship between soil integrity and functional capacity

Functional Capacity Index

The assessment model for deriving the FCI for Maintaining a Characteristic Plant Community is as follows:

$$FCI = \left\{ \left[\frac{\left(\frac{V_{TBA} + V_{SSD}}{2} \right) + \left(\frac{V_{OUS} + V_{DGCS}}{2} \right)}{2} \right] \times \left(\frac{V_{FREQ} + V_{WD} + V_{SOILINT}}{3} \right) \right\}^{1/2} \tag{16}$$

In the first part of the model equation V_{TBA} and V_{SSD} are averaged to provide an indication of the structural components and maturity of the stand. This result is then averaged with the averaged plant diversity variables V_{OUS} and V_{DGCS} to provide an indication of how similar the plant community is to reference standard conditions in terms of structure and species composition. For example, a stand with low basal area (6 m^2/ha), and high understory vegetation density (3,500 /ha) is indicative of an immature stand and would receive a lower FCI. Taking this a step further, a stand with higher basal area (>30 m^2/ha), lower understory vegetation density (1,000/ha) coupled with a high score for diversity (V_{OUS} + V_{DGCS}), represents a mature stand with a characteristic plant community composition and would receive a high FCI.

In the second part of the equation, the abiotic factors that influence the current or future composition and structure of the plant community are considered. The variables V_{FREQ}, V_{WTD}, and $V_{SOILINT}$ are partially compensatory and assumed to be equal and independent and are averaged using an arithmetic mean.

The two parts of the equation are also considered to be independent, and are averaged using a geometric mean based on the assumption that structure, species composition, and abiotic factors contribute equally to the maintenance of a characteristic plant community. If the subindices for the variables in either part of the model decrease, there will be a reduction in the FCI.

Function 8: Provide Habitat for Wildlife

Definition

This function is defined as the ability of a bottomland hardwood forest to support wildlife species that use these wetlands during some part of their life cycles. The focus of attention, however, is on terrestrial wildlife that reside primarily in this habitat for a significant portion of their life cycle. This equation is not based on maximizing species diversity, but maximizing the diversity of the suite of species thought to depend largely on this habitat type. The underlying assumption is that when habitat conditions favor these species, they also will be suitable to provide habitat for other species that use bottomland hardwood forests intermittently or for nonvertebrate species that are indicative of good bottomland hardwood forest habitat.

Rationale for selecting the function

Riverine floodplains and the bottomland hardwood forests associated with them are important to a wide variety of wildlife species. The performance of this function ensures habitat for an entire suite of keystone vertebrate species, contributes to secondary function, maintains complex trophic interactions, and provides for a flow of other wetland-dependent species between this habitat and adjacent areas. Performance of this function also provides refugia and seasonal habitat for wide-ranging and migratory species, as well as corridors for dispersal and migration. Although habitat requirements differ between species, all depend on a suite of physical and geographical conditions that shape habitat quality of bottomland hardwood forests.

Characteristics and processes that influence the function

In riverine, low-gradient wetlands, the input of water from flooding is one of the critical factors influencing wildlife habitat quality. Flooding maintains the characteristic vegetative community that supports the fauna and provides the vector for aquatic species and nutrients to access the area. Flooding also provides conditions necessary for semiaquatic species to complete portions of their life cycles or conditions that limit growth and reproduction. Hydrology is the determining process in shaping the long-term health of characteristic bottomland wetland forests. Access of water to the floodplain may be direct or through surface channels. Natural or created levees may restrict surface connections to riverine wetlands during low flood years; however, extensive areas of a river corridor remain susceptible to flooding during periods of heavy rainfall such as tropical storms.

Low-gradient riverine wetlands are extremely important habitats for numerous fish species. A thorough review of the literature is cited in Ainslie et al. (1999) in their model of riverine systems in western Kentucky. Wharton et al. (1982) provide one of the best overviews of fish use of bottomland forest habitats in the Piedmont and eastern Coastal Plain regions. In this geographical area, which includes this model, at least 20 families and more than 50 species of fish use flooded bottomland forests for foraging and spawning habitat. Baker and Killgore (1994) report similar numbers in the Cache River area of Arkansas.

Temporal and magnitude relationships also may be significant to fish. Lambou (1959) suggested that annual fluctuations in water level limit competition for food, space, and spawning, while Baker and Killgore (1994) found differences in the larval fish catch between years with extensive flooding and years with more sporadic flooding.

Riverine wetlands often are more complex and contain a mosaic of habitat types that vary greatly both temporally and spatially. Such complexity permits the development of a complex fish fauna (Baker, Killgore, and Kasul 1991; Baker and Killgore 1994; Wharton et al. 1982). In its natural state, the floodplain often comprises topographically distinct features determined by its unique historical hydrogeological processes and events such as hurricanes and fires.

In addition to strictly aquatic vertebrate fauna such as fish, riverine wetlands support a rich diversity of semiaquatic and nonaquatic wildlife. Florida has the greatest diversity of reptiles and amphibians of any state in the country (Ashton and Ashton 1988). Many of these species use riverine wetlands for a portion of their life history and some are largely dependent on them (Moler 1992). An endemic species discovered in 1964, the one-toed amphiuma (*Amphiuma pholeter*), seems to be restricted mostly to unique muck habitats confined almost exclusively to riverine forested wetlands (Means, in Moler 1992). Amphibians and some turtles, snakes, and the American alligator can be found with regularity in bottomland forest swamps. Of the 31 recognized species of frogs and toads native to Florida,

18 are considered to be common in bottomland hardwood forests, and 3 others use this habitat less frequently (Ashton and Ashton 1988). Sixteen of 26 salamanders native to Florida use bottomland forest swamps for at least a portion of their life history. Amphibians are greatly influenced by hydrology and respond quickly to subtle changes in hydroperiod and habitat structure. The natural variability of most unaltered bottomland systems serves to support the full diversity of species possible.

The natural floristic and structural complexities of riverine forested wetlands are the principal reasons for their high diversity of terrestrial wildlife (Wharton et al. 1982). The principal of structural diversity determining wildlife diversity has been discussed by numerous ecologists including MacArthur and MacArthur (1961), Cody (1985), Schoener (1986), and Wakeley and Roberts (1996). Hunter (1990) provided a thorough review of the importance of structure to wildlife species diversity.

Floodplain forests are commonly diverse and may contain hundreds of plant species. Wharton et al. (1982) listed more than 50 tree species resident to this community. Forest vegetation is important in producing food crops (Ainslie et al. 1999) and cover, while the heavy leaf fall produces a litter layer important for the same needs in other animals.

Mature forests are likely to be floristically diverse and provide the maximum food and cover values. In Tennessee, the breeding bird density of old growth oak-pine forest was 63 percent greater than in secondary forest (Haney and Lydic 1999). This was partly explained by a higher abundance and distribution of snags and by greater complexity of canopy structure. Snags are used by numerous wildlife species in bottomland forests, and many are dependent on them (Hunter 1990; Scott et al. 1987; Stauffer and Best 1980). Woody debris at the ground layer is another important habitat feature. Logs and woody debris have been shown to be important to a great diversity of species (Harmon, Franklin, and Swanson 1986; Hunter 1990; Loeb 1993; Whiles and Grubaugh 1993). Wharton et al. (1982) listed numerous species from many taxonomic groups that are associated with litter, logs, and crayfish burrows in bottomland hardwood forests.

Landscape-level features of habitat patch size, shape, and connectivity to adjacent habitat types also are important variables that affect wildlife diversity and population numbers (Hunter 1990; Morrison, Marcot, and Twedt 1992; Wilcox and Murphy 1985). A thorough listing of studies that have focused on these issues is given by Shafer (1990). Many of these concepts have originated from the theory of island biogeography presented by MacArthur and Wilson (1967). Although the accuracy of these predictions has been the source of some debate (most notably Abele and Connor 1979; Gilbert 1980; Simberloff 1976), a substantial body of literature has been published that finds these general relationships to fit ecological data for a wide variety of species and habitats.

The species/area relationship has been thoroughly reviewed by various authors (Abbott 1980; Connor and McCoy 1979; Gilbert 1980). Many studies

of mature forested habitats have demonstrated a relationship between species richness and tract size. Willis (1974) studied birds in three Brazilian forest tracts of different sizes that were previously connected in one large forested region. Of the original 203 bird species found in the once-contiguous tract, the largest tract lost 28, the medium tract lost 84, and the smallest lost 127. Most telling was that the largest tract contained those still found in the medium tract and that tract contained the species remaining in the smallest. Species/area relationships also have been demonstrated in Ecuadorian forests (Leck 1979), Panama (Willis 1974), and in Brazil (Lovejoy et al. 1983), among others.

Area is not the only factor responsible for species diversity. Lynch and Whigham (1984) found that the greatest number of bird species in Maryland were influenced by forest physiognomy and vegetative structure, not simply size. Freemark and Merriam (1986) found that larger forests near Ottawa were most beneficial to forest-interior and resident birds, while habitat diversity was most beneficial to edge species. In the Netherlands, Opdam, Rijsdijk, and Hustings (1985) found that area most influenced bird species in mature forest.

Ecologists also have debated the benefits of the "edge effect" since it was first discussed by Leopold (1933). For similar-sized areas, a circular area will have the minimal edge and edge will increase as the area becomes thinner and approaches a straight line. Because edges, both along the perimeter and interior to the tract, seem to favor early successional species, it would seem to be a negative influence to species indicative of mature forested systems, such as bottomland hardwood forests (see discussion in Harris 1988). Noss (1983) also provides a review of the detrimental effects of edge to wildlife. In the design of nature preserves, Diamond and May (1976) make arguments for circular designs over linear ones. The negative effect of edge on keystone mature forest species has been demonstrated for several situations, but is perhaps best demonstrated for cowbirds (*Molothrus ater*) and their nest parasitism of resident forest birds (Robinson et al. 1993, 1995; Robinson 1996).

Another major factor influencing species/area diversity is the land use of adjacent tracts. In forested woodlots in the Netherlands, Opdam, van Dorp, and ter Braak (1984) demonstrated that bird species numbers were significantly affected not only by woodland tract size, but by the acreage of nearby forest blocks and the distance to an extensive forest area. The importance of landscape ecology on the species richness of habitat reserves is a relatively new debate (Shafer 1990), and these concepts are being applied to the debate about preserve design (Means and Greene 1987).

In bottomland hardwood forests, it is especially important for wetland habitats to be connected to uplands. The connection is important so that terrestrial species are able to move away from wetland habitats during periods of flooding (Wharton et al. 1982), for semiaquatic species that require uplands for portions of their life history (e.g., many turtles and amphibians),

and for upland species that use bottomland forests for seasonal habitat needs (e.g., Florida black bears).

Bottomland hardwood forests connected to native vegetated habitats are likely to be more beneficial to forest wildlife than those connected to habitats vegetated by non-natives (e.g., agriculture, suburban landscapes) or to highly disturbed nonvegetated areas (roadways, commercial development). Recent studies, as cited by Ainslie et al. (1999) for birds (Robinson et al. 1995; Thompson et al. 1992, Welsh and Healy 1993), suggest that forest bird populations respond more negatively to fragmentation when adjacent landscapes are converted to agriculture and suburban uses.

Description of model variables

This function is community-based and evaluates wildlife habitat by assessing site-specific and landscape level variables that focus on vertebrate fauna largely dependent on bottomland hardwood forest habitat. The model contains nine variables that represent three major determinants of bottomland hardwood forest wildlife habitat: hydrology, vegetation structure, and landscape configuration. The assumption in this model is that if the habitat requirements of keystone vertebrate species are met, then the habitat needs of other species that use this habitat will be met also. The following variables are grouped by the three major habitat components listed above for the purpose of organization and clarity. These variables assess the ability of the bottomland hardwood forest to support wildlife populations based on the physical structure of the vegetation and landscape considerations.

Overbank Flood Frequency (V_{FREQ}). This variable represents the annual frequency at which water from a stream overtops its banks (i.e., exceeds channel-full discharge) and inundates bottomland hardwood forest habitat on the floodplain. Overbank flooding maintains a characteristic plant community, which, in turn, ensures a characteristic wildlife community. Normal, annual flood cycles maintain necessary soil and leaf litter conditions, provide pools of surface water necessary for many species to complete their life cycles, and restrict the ability of many non-native plant species to establish successfully.

Recurrence interval in years is used to quantify this variable. The procedure for measuring this variable is described under Function 1.

In west-central peninsular Florida reference wetlands, using the regional curve or equations from the ratio or regression approach produced recurrence intervals ranging from 1 to 100 years (Appendix D). Based on the range of values from reference standard sites, a variable subindex of 1.0 is assigned to recurrence intervals ≤3 years (Figure 39). Longer recurrence intervals are assigned a linearly decreasing subindex to 0.1 at a recurrence interval of 10 years. This is based on the assumption that where entrenchment, channelization, or levees effectively increase the depth of the stream channel, a greater discharge is required to overtop the bank and inundate

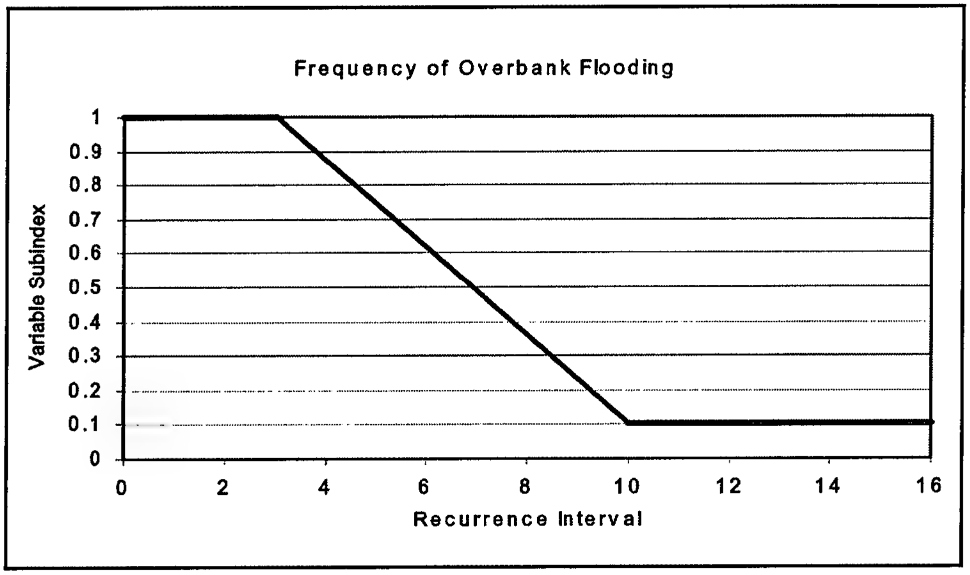

Figure 39. Relationship between frequency of overbank flooding and functional capacity

the riverine wetland. The rationale for the rate at which the subindex drops to 0.1 (i.e., 1.0 to 0.1) is based on the assumption that as frequency increases, the capacity of the wetland to store annual peak discharges decreases to one-tenth the amount of water stored over a period of 10 years under reference standard conditions. Model validation will help to define the actual nature of this relationship. Recurrence intervals >10 years are assigned a subindex of 0.1. This is based on the assumption that even at longer recurrence intervals, floodplain forests provide some habitat for wildlife species.

Extent of Ponding (V_{POND}). This variable is defined as the percentage of the riverine wetland that is capable of ponding surface water (i.e., water source precipitation, overland flow, or groundwater discharge) for extended periods of time. Abandoned channels are typical topographic relief features that impound water. Features that are capable of holding water on a semipermanent basis and lack outlets contribute to the expression of this variable. This is important because bottomland hardwood forests are important areas for finfish spawning and feeding (Wharton et al. 1981; Lambou 1990). High densities of invertebrates are found in wet depressions of floodplain forests (Gladden and Smock 1990). Many species of reptiles and amphibians are prevalent in bottomland hardwood forests as these temporary reservoirs play a significant role in contributing to the needs of these species and their various life cycles (Wharton et al. 1982; Porter 1972). Depressional surface water in bottomland hardwood forests can also moderate temperature extremes and serve as escape habitat for wildlife (Harris 1989).

Field reconnaissance, topographic maps, and aerial photographs can be used to estimate this feature. Report the percentage of the area being assessed that is capable of ponding surface water.

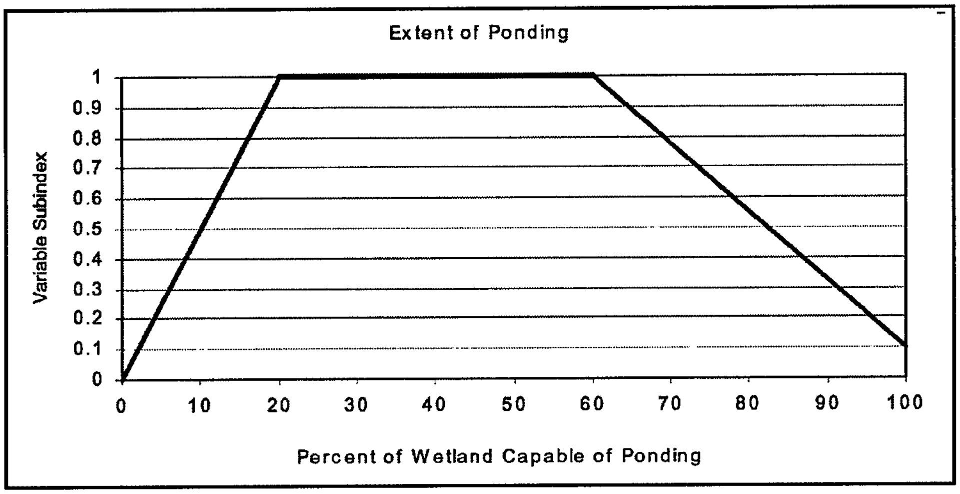

Figure 40. Relationship between extent of ponding and functional capacity

Extent of ponding in reference standard wetlands was 25-50 percent. When the extent of ponding is between 20 percent and 60 percent of the site, a subindex of 1.0 is assigned (Figure 40). When the extent of ponding is <20 percent, a variable decreasing subindex down to zero at zero is assigned. This is based on the assumption that as depressional surface water areas decrease in bottomland hardwood forests, the ability to offer escape habitat and support various life cycles for many wildlife species is reduced or lost. Sites with greater than 60 percent ponding would be predominantly covered by water and are given a variable decreasing subindex of 0.1 at 100 percent ponding. This condition would be detrimental to many terrestrial species although other species may benefit, and it would result in an atypical plant community, again benefiting only the few.

Wetland Tract Area (V_{TRACT}). This variable is the area of bottomland hardwood forest and any contiguous wetland forest of other related subclasses (i.e., cypress swamp, hydric and mesic hammock, bay swamp) that is contiguous and directly accessible to wildlife from the area being assessed. In the context of this function, this variable represents the assumption that wildlife in Florida that require bottomland hardwood forest are not likely to distinguish this habitat from other wetland forests and routinely use all of them. Although the exact relationship between habitat area and species diversity is often confused by other factors such as habitat quality and diversity, the literature generally supports a correlation between wildife species diversity and area for forest species (Hamel 1989; Harris 1989; Pickett and White 1985).

Measure the Wetland Tract Area using the following procedure:

(1) Determine the size of the area of wetland of the same regional subclass and related subclasses listed in the previous paragraph that are continuous with the assessment area using field reconnaissance, topographic maps, NWI maps, or aerial photography.

(2) Record the size of the area in hectares.

In west-central peninsular Florida reference wetlands, wetland tract size ranged from 2 to 4,300 ha (Appendix D). This range assumes that two-lane state highways and powerline corridors do not represent significant barriers to most wildlife. Larger roads and discontinuities were treated as tract boundaries. Based on data from reference standard sites in peninsular Florida and faunal studies in forested tracts in general (Blake and Hoppes 1986; Blake and Karr 1984; Harris 1989; Robbins, Dawson, and Dowell 1989; Temple 1986; Whitcomb et. al. 1981), a variable subindex of 1.0 is assigned when wetland tract size is ≥600 ha (1,500 acres) since the most sensitive wildlife component strongly tied to this habitat, interior forest birds, seems to be able to maintain its populations at this threshold. As the wetland tract size decreases, a linearly decreasing subindex is assigned down to 0 at an index of 0 (Figure 41).

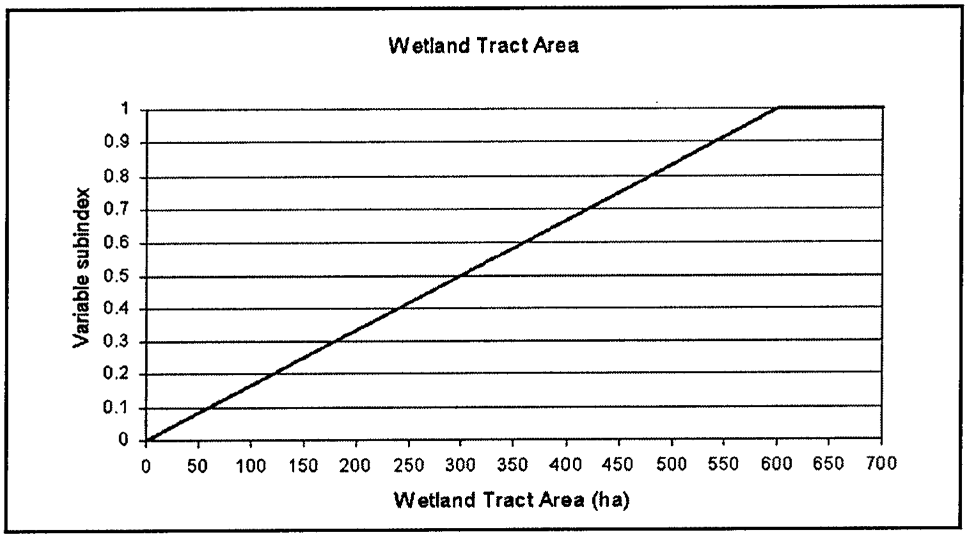

Figure 41. Relationship between wetland tract area and functional capacity

Habitat Connections ($V_{CONNECT}$). This variable is defined as the percentage of the perimeter of the bottomland hardwood forest that is connected to other native habitat, which directly influences the edge effect. Wildlife frequently use more than one habitat type during their lifetime or as part of their normal life cycle. Connections to habitats other than bottomland hardwood forest may provide critical linkages or corridors necessary to the species. Additionally, such connection provides a natural buffer from invasive alien flora and fauna. Edge may increase wildife species diversity, but it does so often by adding species that are not or are poorly adapted to the core area habitat. Edge also greatly increases the possible negative impacts of non-native or habitat-foreign species, including parasitism and predation, and habitat alterations.

Definitions of habitat types are as follows:

(1) Suitable habitats are other native natural habitats, whether forested or not.

(2) Habitats that are considered less suitable are unnatural vegetated habitats. These include habitats of mostly native plants that are not natural assemblages and habitats vegetated mostly by non-native species. Low-density suburban landscapes could be considered less suitable habitat if these landscapes were mostly vegetated in the manner described.

(3) Unsuitable habitats are areas mostly devoid of vegetation, such as recently cleared ground, roadways and parking lots, and areas of commercial development.

An adjacent habitat is considered connected when it is directly adjacent and the width of this habitat class is at least 0.4 km. If the width is less than 0.4 km, then the next adjacent habitat class is considered to be the adjacent habitat class.

The percentage of the perimeter of the bottomland hardwood forest that is "connected" is used to quantify this variable. Measure it using the following procedure:

(1) Measure the perimeter lengths of the bottomland hardwood forest perimeter that is adjacent to the three habitat types: Suitable habitat, Less Suitable habitat, and Unsuitable habitat

(2) Divide the perimeter length of each habitat type separately by the total perimeter obtained by summing all three types.

(3) Multiply each type by 100 to obtain a percentage.

(4) Multiply each percentage by the assigned multipliers for each type: Suitable habitat = 1, Less Suitable habitat = 0.7, Unsuitable habitat = 0.1.

(5) Sum the total and report wetland tract perimeter as a percentage.

Table 13 provides an example of the calculation with 3,600 ft (1,097 m) of wetland tract perimeter as Suitable habitat, 1,000 ft (305 m) of wetland tract perimeter as Less Suitable habitat, and 500 ft (152 m) of wetland tract

Table 13
Calculating Habitat Connections (*$V_{CONNECT}$*)

Forest Perimeter Type and Corresponding Variable Subindex	Perimeter, ft (m)	Determine Percent of Perimeter, Multiply by Variable Subindex	Calculated Percent
Suitable Habitat = 1	3,600 (1,097)	(3,600/5,100) × 100 = 70 percent 70 percent × 1	70
Less Suitable Habitat = 0.7	1,000 (305)	(1,000/5,100) × 100 = 20 percent 20 percent × 0.7	14
Unsuitable Habitat = 0.1	500 (152)	(500/5,100) × 100 = 10 percent 10 percent × 0.1	1
Total	5,100 (1,554)		
		Calculated Percent of Connected Wetland Perimeter	85

perimeter as Unsuitable habitat for a total of 5,100 ft (1,554 m) of wetland tract perimeter that is connected (see Appendix D for site examples of determining perimeter types).

The Suitable habitat type was assigned a multiplier of 1; the Less Suitable habitat type was assigned a multiplier of 0.7; and the Unsuitable habitat type was assigned a multiplier of 0.1. The percentages were multiplied by the corresponding multipliers and added together resulting in a range from 100 percent to 10 percent. Reference standard sites with ranges from 100 percent to 75 percent received a variable subindex of 1. Reference sites ranging below 75 percent received a linearly decreasing subindex of 0.1 at a range of 10 percent (Figure 42). This is based on the assumption that as Suitable combined with Less Suitable connections decrease to Unsuitable, or no connections, so does the suitability for wide-ranging species or those that move to upland habitat during periods of prolonged inundation. However, when 100 percent of the wetland perimeter is Unsuitable, a variable subindex of 0.1 is assigned because some wildlife species such as birds and fish are capable of movement into other habitats and may benefit from the wetland itself.

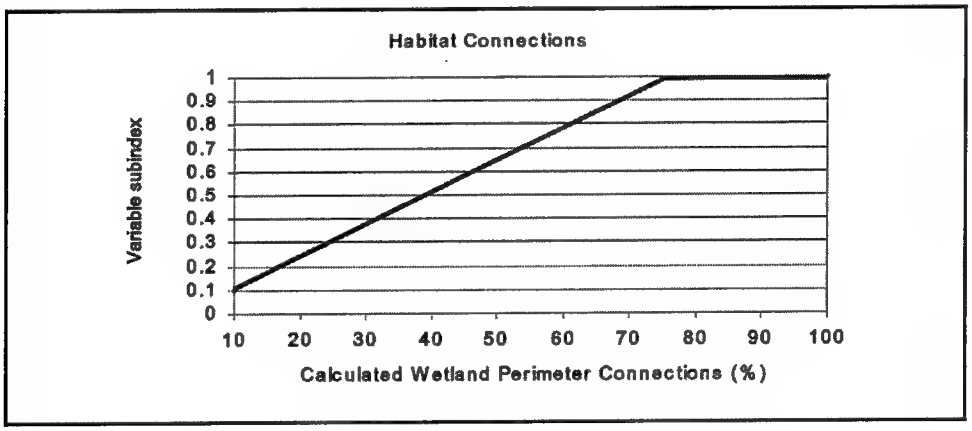

Figure 42. Relationship between habitat connections and functional capacity

Overstory and Understory Species Composition (V_{OUS}). This variable represents the diversity of overstory and understory plants in bottomland hardwood forests. In general, a mature forest with characteristic plant species will support the greatest diversity of characteristic wildlife. Immature stands, stands altered by non-natural forces and containing noncharacteristic plant species (including those with greater actual vegetational diversity), and altered stands with reduced plant diversity all should support a reduced diversity and/or number of wildlife indicative of this habitat class. Wildlife habitat values are directly dependent on plant composition. Therefore, characteristic bottomland plant species composition should be expected to provide habitat necessary for bottomland forest wildlife species.

Measure plant species composition using the procedure described under Function 7.

In west-central peninsular Florida reference wetlands, the FQI based on overstory and understory vegetative layers ranged from 50 to 200 (Appendix D). Based on the data from reference standard sites supporting mature and fully stocked forests, a variable subindex of 1.0 was assigned when FQI scores ranged from 190 to 200. As the FQI index decreases a linearly decreasing subindex is assigned down to zero at an index of zero (Figure 43). This is based on the assumption that the relationship between overstory and understory plant species composition and the capacity of the riverine wetland to maintain a characteristic plant community is linear.

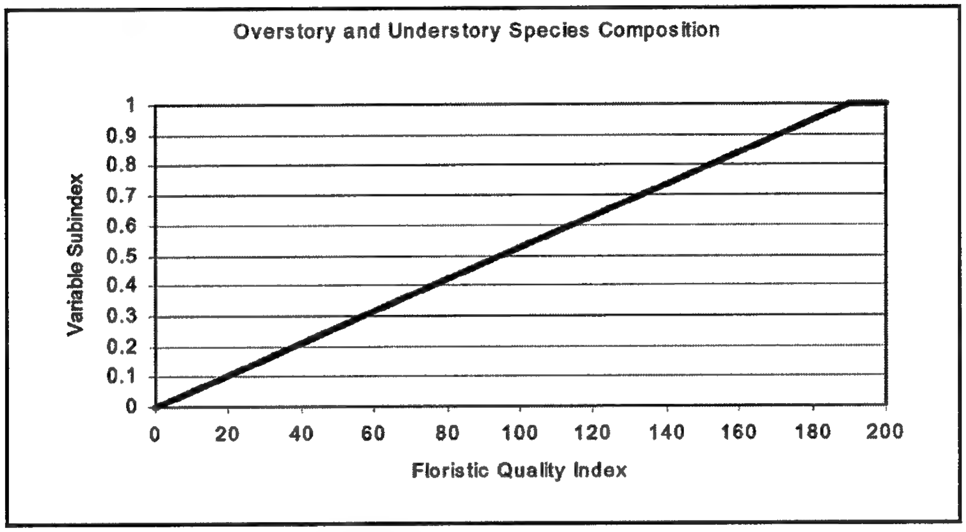

Figure 43. Relationship between overstory and understory species composition and functional capacity

Tree Biomass (V_{TBA}). This variable represents the relative age and health of the stand as represented by the tree stratum. Trees are defined as woody stems ≥6 m in height and ≥10 cm dbh (Bonham 1989). Diameter is by convention measured at 1.3 m above ground level and can be easily converted to basal area. Basal area is the area occupied by the tree stems and represents the mass of organic material per unit area in the tree stratum. Basal area, or tree biomass, is closely related to stand development and maturity (Brower and Zar 1984), and represents the simplest form of forest stand characterization. In the context of this function mature tree basal area >10 cm dbh serves as an indicator of plant community structure and maturity. Tree basal area is used to quantify this variable measure it using the procedures described in the discussion of "Tree Biomass (V_{TDBH})" variable under Function 3.

In west-central peninsular Florida reference wetlands, tree basal area ranged from 0 to 73 m^2/ha (Appendix D). Based on the data from reference standard sites supporting mature and fully stocked forests, a variable subindex of 1.0 is assigned when basal area is ≥30 m^2/ha (Figure 44). At reference sites that have been cleared or are in middle to early successional stages, tree basal area is less, and consequently a subindex linearly decreasing to zero at zero basal area is assigned. This is based on the assumption

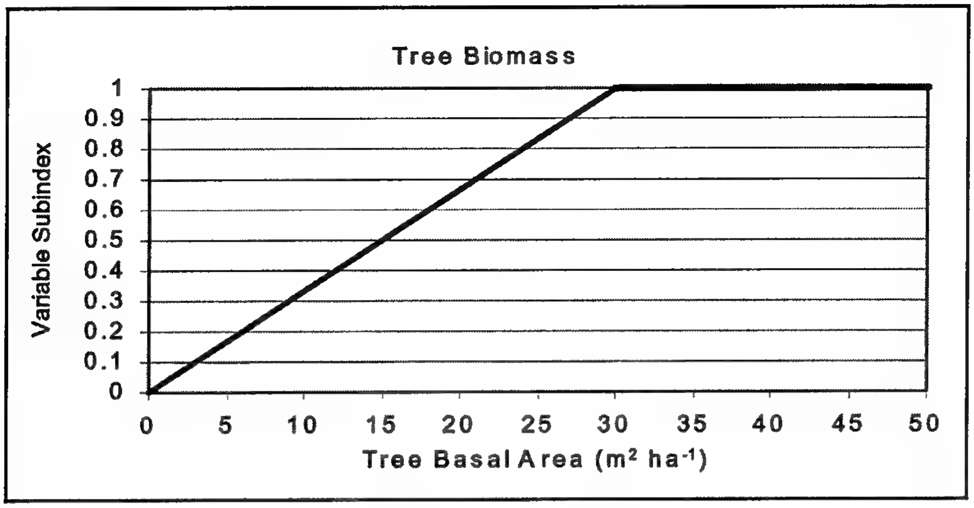

Figure 44. Relationship between tree biomass and functional capacity

that the relationship between tree basal area and the capacity of the riverine wetland to maintain a characteristic plant community is linear. This assumption could be validated with data from a variety of low-gradient riverine wetlands in the southeast summarized by Clewell, Goolsby, and Shuey (1982); Leitman, Sohm, and Franklin (1983); Brinson (1990); Sharitz and Mitsch (1993); and Messina and Conner (1997), or the independent, quantitative measures of the function identified in the previous paragraph.

Understory Vegetation Biomass (V_{SSD}). This variable represents the number of shrubs and saplings per unit area in riverine wetlands. Shrubs and saplings, understory vegetation, are defined as woody stems >1 m in height and <10 cm dbh. Shrub and sapling stem density is inversely related to basal area in mature riverine forests. That is, as tree basal area increases with maturity, shrub and sapling density decreases. Therefore, understory vegetation density can serve as an indicator of habitat structure. Measure understory vegetation density using the procedures given for this variable under Function 3.

In west-central peninsular Florida reference wetlands, understory vegetation stem density ranged from 0 to nearly 2,500 stems/ha (Appendix D). Based on data from reference standard sites, a variable subindex of 1.0 is assigned when understory vegetation stem density is between 150 and 1,400 stems/ha (Figure 45). As understory stem density decreases, a subindex linearly decreasing to zero at zero stems/ha is assigned. This is based on the assumption that if understory vegetation does not exist, it does not contribute to habitat structure or as food source for wildlife. As understory vegetation stem density increases above 1,400 stems/ha, a linearly decreasing subindex is assigned down to 0.5 at 1,900 stems/ha. Above 1,900 stems/ha a subindex of 0.5 is assigned. The rationale for this is that it is common for understory stem density to exceed 500 stems/ha during the middle stages of succession (Whittaker 1975). As the forest matures, competition for resources results in a decrease in understory stem density to the levels

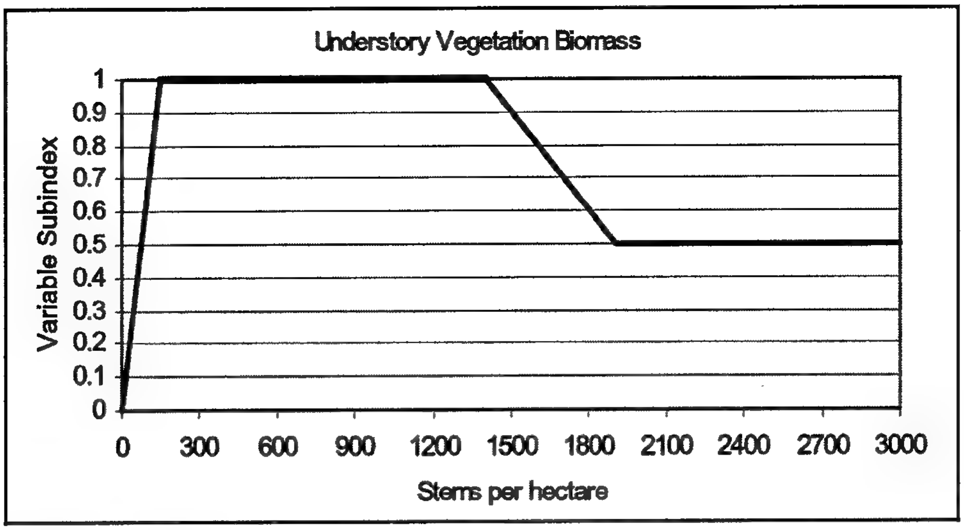

Figure 45. Relationship between understory vegetation biomass and functional capacity

observed at reference standard sites. The rate at which the subindex increases, decreases, and levels out above 1,700 stems/ha represents an educated guess of the relationship between understory stem densities and a characteristic habitat structure and food sources for wildlife. These assumptions could be validated using the data from a variety of low-gradient riverine wetlands in the southeast using the independent, quantitative measures of function identified in the previous paragraph.

Woody Debris Biomass (V_{WD}). This variable represents the total mass of organic matter contained in woody debris on or near the surface of the ground. Woody debris is defined as down and dead woody stems ≥0.25 in. (6 mm) in diameter that are no longer attached to living plants. Despite its relatively slow turnover rate, woody debris is an important component of food webs and nutrient cycles of temperate terrestrial forests (Harmon, Franklin, and Swanson 1986), and in the context of this function accounts for the contribution woody debris makes to provide habitat and food sources for wildlife.

Volume of woody debris per hectare is used to quantify this variable. Measure it with the procedure described for this variable under Function 3.

In west-central peninsular Florida reference wetlands, the volume of woody debris ranged from 0 to 304 m^3/ha (Appendix D). Based on data from reference standard sites, a variable subindex of 1.0 is assigned to sites with woody debris between 60 and 150 m^3/ha (Figure 46). Below 60 m^3/ha the subindex decreases linearly to 0. This range of values included reference sites that had been converted to agriculture and had little or no woody debris, sites in early stages of succession with low volumes of woody debris, and sites in the middle stages of succession with a volume of woody debris between 4 and 56 m^3/ha. The decrease in the variable subindex is based on the assumption that lower volumes of woody debris indicate an

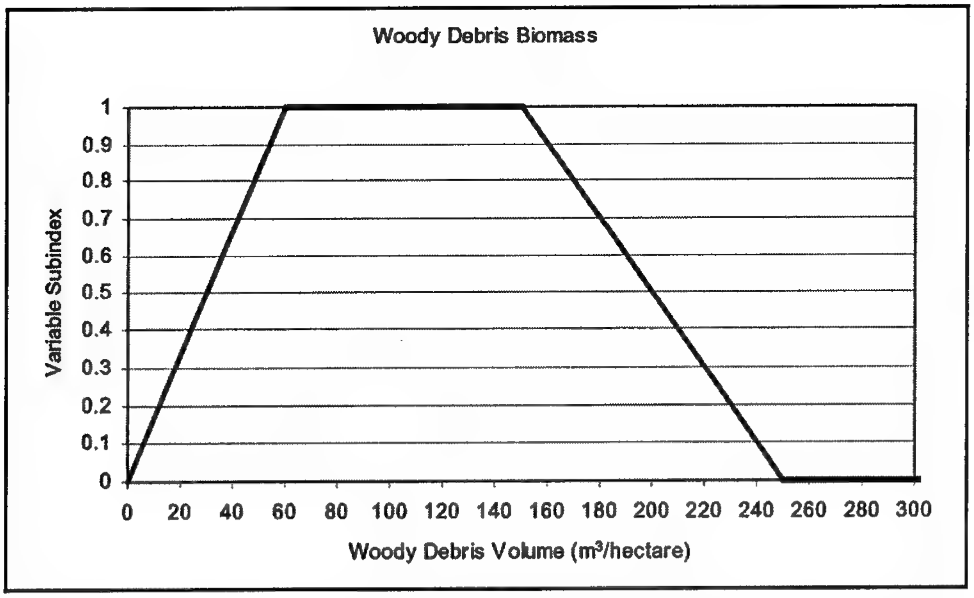

Figure 46. Relationship between woody debris biomass and functional capacity

inadequate amount of twigs, branches, and downed logs that are necessary habitat for many types of wildlife. Above 150 m^3/ha the subindex decreases linearly to 0 at 250 m^3/ha. This is based on the assumption that increasingly higher volumes of woody debris that result from logging will result in abnormal habitat conditions.

O Horizon Biomass (V_{OHOR}). This variable represents the total mass of organic matter in the O horizon. The O horizon is synonymous with the detrital or litter layer and is the soil surface layer dominated by recognizable and partially to highly decomposed organic matter such as leaves, needles, sticks, or twigs <0.6 cm in diameter, flowers, etc. (USDA SCS 1993). In the context of this function, this variable represents the importance of this layer for the growth of vegetation and the subsequent production of food and shelter for wildlife. Relative volume of the O horizon is used to quantify this variable. Measure the O horizon using the procedures described for this variable under Function 3.

In west-central peninsular Florida reference wetlands, percent O horizon cover measured 100 percent (Appendix D). Based on data from reference standard sites, a variable subindex of 1.0 is assigned when the O soil horizon is 100 percent (Figure 47). As O horizon cover decreases, a subindex linearly decreasing to zero at zero percent cover is assigned. The rate at which the subindex decreases, and the selection of 0 as the subindex at zero percent cover, are based on the assumption that the relationship between O soil horizon cover and litter habitat and detrital food webs are linear, and that a decreasing amount of biomass in the tree, sapling, shrub and ground vegetation strata of the plant community is reflected in lower percent O soil horizon cover. When percent O soil horizon declines to zero, litter habitat and detrital food webs have essentially ceased. These assumptions could be validated by analyzing the relationship between O soil horizon

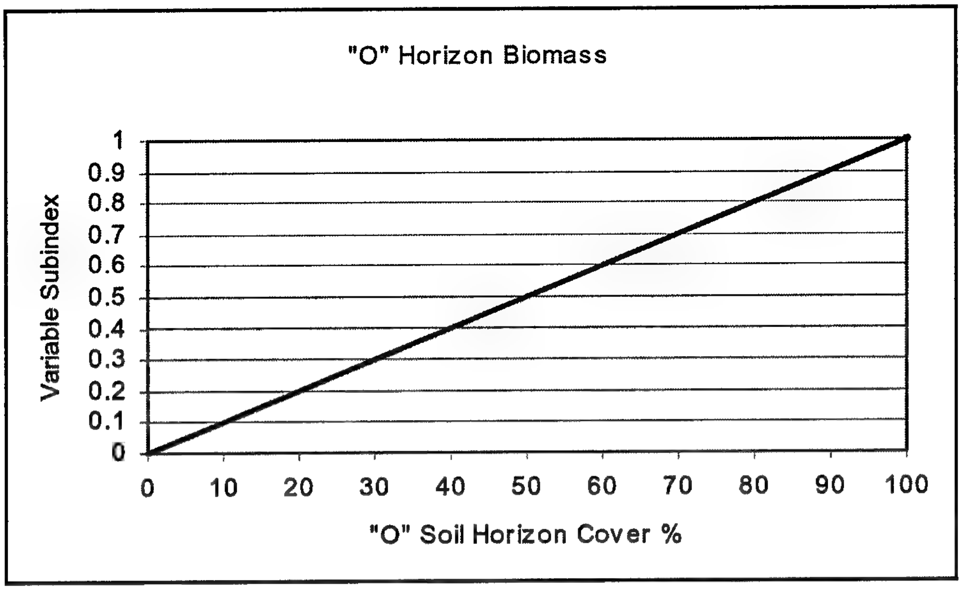

Figure 47. Relationship between O horizon biomass and functional capacity

cover and the capacity to maintain litter habitat and detrital food webs using data from a variety of low-gradient riverine wetlands in the southeast as summarized by Wharton et al. (1982), Sklar and Conner (1979), and Grey (1973), or the independent, quantitative measures of the function defined in the previous paragraph.

Functional Capacity Index

The aggregation equation for deriving the FCI for Providing Habitat for Wildlife is as follows:

$$FCI = \left[\frac{\left(\frac{V_{FREQ} + V_{POND}}{2}\right) + \left(\frac{V_{TRACT} + V_{CONNECT}}{2}\right)}{2} \times \frac{\left(\frac{V_{SSD} + V_{OUS} + V_{TBA}}{3}\right) + \left(\frac{V_{WD} + V_{OHOR}}{2}\right)}{2} \right]^{\frac{1}{2}} \quad (17)$$

This model is assumed to reflect composition and abundance of avian and other wildlife species in the riverine low-gradient subclass. If all these components are similar to reference standard condition (i.e., a large, diverse, unfragmented, mature forested system that floods regularly), there is a high probability that the full complement of birds (and by inference other groups such as small and large mammals, reptiles, amphibians, fish, and invertebrates) typically associated with forested wetlands will be present. The variables have been grouped by the three major components of hydrology, landscape, and biotic community. It should be noted that the emphasis is on onsite conditions. Even in largely fragmented landscapes, if reference standard conditions exist onsite, the majority of fish and wildlife species will be present. However, the site would not support some (10-15) area sensitive species of interior birds and large carnivores.

Frequency of overbank flow V_{FREQ} is used in this function because a site must flood regularly for species that require water or moist conditions (amphibians and litter invertebrates) to use the wetland. V_{FREQ} also is used to assess whether or not fish and other aquatic organisms can obtain regular access to the floodplain. The assumption is that annual flooding provides optimal access by aquatic organisms. V_{POND} represents the presence of permanent or semipermanent water in the wetland. V_{POND} is an indicator of the surface complexity of the wetland indicative of a diverse ecosystem capable of supporting a diversity of fish and wildlife. V_{POND} is considered independent of V_{FREQ} since ponding of surface water can occur from water sources besides overbank flow and ponding is not always a consequence of flooding. Therefore, ponded areas may occur within the wetland in the absence of flooding, and conversely, flooding may occur with no resulting ponding. Thus V_{POND} and V_{FREQ} are averaged.

The habitat structure has both living and detrital components. The living portion is represented by the variable V_{OUS}, a reflection of the characteristic plant community to reference standards, V_{SSD}, and V_{TBA}, a measure of stand maturity, providing an indication of seral stage. It is assumed that a mature stand composed of species reflective of late seral stages (generally oak-dominated) represents a diverse, stable community with diverse, stable wildlife populations. V_{SSD} and V_{TBA} also provide an indicator of forest stand structure. The assumption is that as the stand matures, structure will become more diverse and provide more wildlife habitat. The volume of woody debris V_{WD} represents the amount of cover, foraging, and reproductive sites available for a variety of wildlife species. Leaf liter V_{OHOR} represents habitat for invertebrates and selected small mammals. V_{WD} and V_{OHOR} are considered independent of one another and are averaged to account for minor structural components of habitat.

The variables wetland tract area V_{TRACT} and habitat connections $V_{CONNECT}$ reflect large-scale attributes of the wetland and of the landscape in which the wetland is located. The assumption is the more habitat available, the more wildlife utilization will occur. Essentially, these variables represent two components: size V_{TRACT} and isolation of the wetland from adjacent suitable habitats $V_{CONNECT}$.

In the first subpart of the aggregation equation the variables representing hydrology are considered equal and are averaged. V_{FREQ} represents delivery of the water to the wetland surface and V_{POND} represents detention of water. In the second subpart of the equation the landscape level features V_{TRACT} and $V_{CONNECT}$ are considered independent and of equal weight and consequently are averaged. Landscape is considered to exert an equivalent influence on the function; therefore it is averaged with hydrology. In the third subpart of the equation V_{SSD}, V_{OUS}, V_{TBA}, V_{WD}, and V_{OHOR} represent the plant community structure (both living and dead). The first three variables are considered of equal weight and consequently averaged. The latter two variables represent significant but somewhat less important structural conditions and are averaged separately. The onsite community represents the composition and structural components of habitat and are

considered to exert a controlling influence on the function. Thus, the hydrology and landscape components are multiplied by the onsite community and averaged by a geometric mean. The arrangement of the aggregation equation reflects the assumption that site-specific aspects of habitat (i.e., biotic community/habitat structure) carry greater weight than landscape features. In other words, if the onsite community is degraded, the use of that wetland area by wildlife species will decrease even in a relatively unfragmented landscape with intact hydrology.

5 Assessment Protocol

Introduction

Previous sections of this Regional Guidebook provide background information on the HGM Approach, and document the variables, measures and models used to assess the functions of low-gradient, riverine wetlands in west-central Florida. This chapter outlines a protocol for collecting and analyzing the data that is necessary to assess the functional capacity of a wetland in the context of a 404 permit review process or similar assessment scenario.

The typical assessment scenario is a comparison of preproject and postproject conditions in the wetland. In practical terms, this translates into an assessment of the functional capacity of the WAA under both preproject and postproject conditions and the subsequent determination of how FCIs have changed as a result of the project. Data for the preproject assessment are collected under existing conditions at the project site, while data for the postproject assessment are normally based on the conditions that are expected to exist following proposed project impacts. A skeptical, conservative, and well-documented approach is required in defining postproject conditions. This recommendation is based on the often-observed lack of similarity between predicted or "engineered" postproject conditions and actual postproject conditions.

This chapter discusses each of the tasks that are required to complete an assessment of low-gradient riverine wetlands in west-central Florida:

a. Define assessment objectives.

b. Characterize the project site.

c. Screen for red flags.

d. Define the WAA.

e. Collect field data.

f. Analyze field data.

g. Apply assessment results.

Complete Preassessment Tasks

Define assessment objectives

Begin the assessment process by unambiguously identifying the purpose for conducting the assessment. This can be as simple as stating, "The purpose of this assessment is to determine how the proposed project will impact wetland functions." Other potential objectives could be the following: (a) compare several wetlands as part of an alternatives analysis; (b) identify specific actions that can be taken to minimize project impacts; (c) document baseline conditions at the wetland site; (d) determine mitigation requirements; (e) determine mitigation success; or (f) determine the effects of a wetland management technique.

Frequently, multiple purposes will be identified for conducting the assessment. Defining the purpose will facilitate communication and understanding among the people involved in conducting the assessment, and will make the purpose clear to other interested parties. In addition, it will help to establish the approach that is taken. The specific approach will vary to some degree depending on whether the project is a Section 404 permit review, an Advanced Identification (ADID), Special Area Management Plan (SAMP), or some other scenario.

Characterize the project area

Characterizing the project area involves describing the project area in terms of climate, surficial geology, geomorphic setting, surface water and groundwater hydrology, vegetation, soils, land use, proposed impacts, and any other characteristics and processes that have the potential to influence how wetlands at the project area perform functions. The characterization should be written, and accompanied by maps and figures that show project area boundaries, jurisdictional wetlands, WAA (discussed in a later paragraph), proposed impacts, roads, ditches, buildings, streams, soil types, plant communities, threatened or endangered species habitat, and other important features. Some information sources that will be useful in characterizing a project area are aerial photographs, topographic and NWI maps, and county soil surveys.

Screen for red flags

Red flags are features within or in the vicinity of the project area to which special recognition or protection has been assigned on the basis of objective criteria (Table 14). Many red flag features, such as those based on national criteria or programs, are similar from region to region. Other red flag features are based on regional or local criteria. Screening for red flag features represents a proactive attempt to determine if the wetlands or other natural resources in and around the project area require special

Table 14
Red Flag Features and the Respective Program/Agency Authority

Red Flag Features	Authority
Native lands and areas protected under American Indian Religious Freedom Act	A
Areas supporting threatened or endangered species	F, H, J
City, county and state parks	F, M
Areas protected by a Coastal Zone Management Plan	B, E, F, M
Areas protected by the Marine Protection Research and Sanctuaries Act	E, B, M, F
Areas with structures and/or artifacts of historic or archaeological significance	G
Hazardous waste sites identified under CERCLA (Super Fund) or Resource Conservation and Recovery Act (RCRA)	I, J
Areas providing critical habitat for species of special concern	J, F, H
National Wildlife Refuges and Special Management Areas	J, F
Areas identified in the North American Waterfowl Management Plan	J, F
Areas designated as sole source groundwater aquifers	M
Floodplains, floodways or floodprone areas	K, M
Areas covered under the Farmland Protection Act	L, M
Areas protected under the Land and Water Conservation Fund Act	L, M
Areas identified as significant under the Ramsar Treaty	C
Areas supporting rare or unique plant communities	J, F, H
Areas protected by the Safe Drinking Water Act	M, I
Areas with unique geological features	H, M
Areas protected by the Wild and Scenic Rivers Act	J, F
Areas protected by the Wilderness Act	J, F

Program Authority/Agency
A Bureau of Indian Affairs
B National Marine Fisheries Service
C International Convention on Protection of Wetlands
D National Park Service
E State Coastal Zone Office
F State Departments of Natural Resources, Fish and Game, etc.
G State Historic Preservation Office
H State Natural Heritage Office
I U.S. Environmental Protection Agency
J U.S. Fish and Wildlife Service
K Federal Emergency Management Administration
L National Resource Conservation Service
M Local government agencies

consideration or attention that may preempt or postpone an assessment of wetland function. If a red flag feature exists, the assessment of wetland functions may not be necessary if the project is unlikely to occur as a result of the red flag feature. For example, if a proposed project has the potential to impact a threatened or endangered species or habitat, an assessment of wetland functions may be unnecessary since the project may be denied or modified strictly on the basis of the impacts to threatened or endangered species or habitat.

Define the Wetland Assessment Area

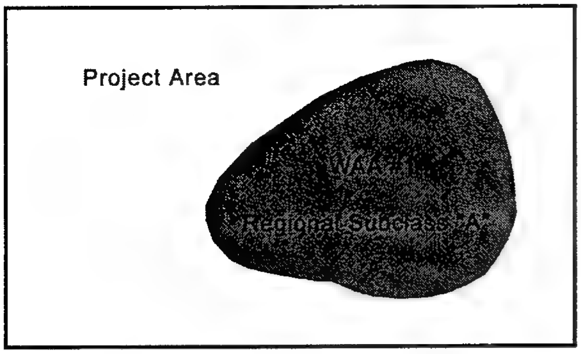

Figure 48. A single WAA within a project area

The WAA is an area of wetland within a project area that belongs to a single regional wetland subclass, and is relatively homogenous with respect to the site-specific criteria used to assess wetland functions (i.e., hydrologic regime, vegetation structure, topography, soils, successional stage, etc.). In many project areas, there will be just one WAA representing a single wetland subclass as illustrated in Figure 48. However, as the size and heterogeneity of the project area increase, it is more likely that it will be necessary to define and assess multiple WAA's within a project area.

At least three situations necessitate defining and assessing multiple WAA's within a project area. The first situation exists when widely separated wetland patches of the same regional subclass occur in the project area (Figure 49). The second situation exists when more than one regional wetland subclass occurs within a project area (Figure 50). The third situation exists when a physically contiguous wetland area of the same regional subclass exhibits spatial heterogeneity with respect to hydrology, vegetation, soils, disturbance history, or other factors that translate into a significantly different value for one or more of the site-specific variable measures. These differences may be a result of natural variability (e.g., zonation on large river floodplains) or cultural alteration (e.g., logging, surface mining, hydrologic alterations) (Figure 51). Designate each of these areas as a separate WAA and conduct a separate assessment on each one.

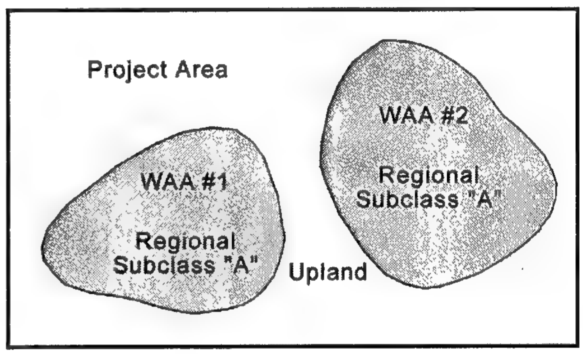

Figure 49. Spatially separated WAA from the same regional wetland subclass within a project area

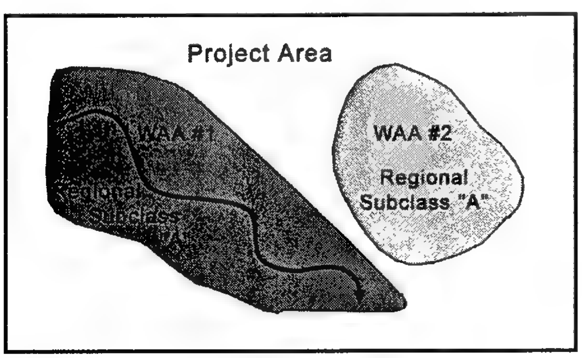

Figure 50. More than one regional wetland subclass within a project area

There are elements of subjectivity and practicality in determining what constitutes a significant difference in portions of the WAA. Field experience with the regional wetland subclass under consideration should provide the sense of the range of variability that typically occurs, and the common sense necessary to make reasonable decisions about

defining multiple WAA's. For example, in west-central Florida, recently abandoned cropland, mined areas, and land harvested for timber will be three common criteria for designating two WAA's in a wetland area. Splitting an area into many WAA's in a project area based on relatively minor differences resulting from natural variability should not be used as a basis for dividing a contiguous wetland into multiple WAA's. However, zonation caused by different hydrologic regimes or disturbances caused by rare and destructive natural events (i.e., hurricanes) should be used as a basis for defining WAA's.

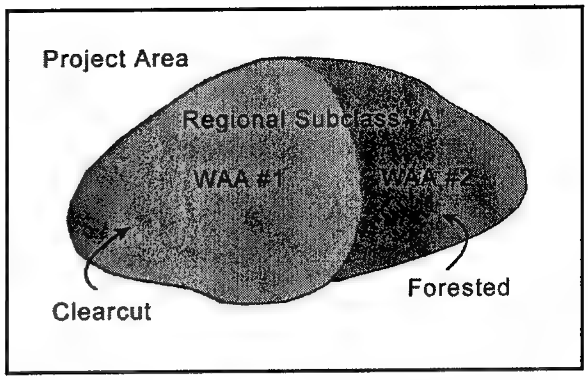

Figure 51. WAA defined based on differences in site-specific characteristics

Collect Field Data

The following equipment is necessary to collect field data:

- Plant identification keys
- Soil probe/sharpshooter shovel
- Munsell color book and hydric soil indicator list (USDA NRCS 1998)
- Diameter tape or calipers for measuring tree basal area
- 50-m distance measuring tape, stakes, and flagging

Information about the variables that are used to assess the function of low-gradient riverine wetlands in west-central Florida is collected at several different spatial scales. The Field Datasheet shown in Figure 52 is organized to facilitate data collection at each spatial scale. Information about landscape scale variables (i.e., variables 1-5 on the Field Datasheet) such as land use, is collected using aerial photographs, maps, and field reconnaissance of the area surrounding the WAA. Subsequently, information about the WAA in general (i.e., variables 6-14) is collected during a walking reconnaissance of the WAA. Finally, detailed site-specific information (i.e., variables 15-22) is collected using sample plots and transects (using the Plot Worksheet (Figure 53)).

The layouts for these plots and transects are shown in Figure 54 (circular plot) and Figure 55 (square plot). The exact number and location of these sample plots and transects are dictated by the size and heterogeneity of the WAA (Davis 1998). If the WAA is relatively small (i.e., less than 2-3 acres (0.8-1.2 ha)) and homogeneous with respect to the characteristics and processes that influence wetland function, then three or four sample points in representative locations are probably adequate to characterize the WAA.

Field Data Sheet
Low Gradient Riverine Wetlands in West Central Peninsular Florida

Assessment Team: ______________________________

Project Name/Location: ______________________________ Date: ____________

Sample variables 1-4 using aerial photos, topographic maps, scenic overlooks, local informants, tables, surveys, etc.

1. V_{TRACT} — Area of wetland that is contiguous with the WAA *and* of the same subclass _____ha
2. $V_{CONNECT}$ — Percent of wetland tract perimeter that is "connected" to suitable habitat ….._____%
3. V_{SLOPE} — Percent floodplain slope…………………………………………………….._____%
4. V_{STORE} — Floodplain width to channel width ratio……………………………………..._____

Sample variables 5-14 based on a walking reconnaissance of the WAA.

5. V_{FREQ} — Overbank flood recurrence interval…………………………………………..._____yrs
   Check data source: gage data__, local knowledge__, flood frequency curves__, Regional dimensionless curve__, hydrologic modeling__, other___________.
6. V_{ROUGH} — Roughness Coefficient:
   0.026 (n_{BASE}) + ___ (n_{TOPO}) + ___ (n_{OBS}) + ___ (n_{VEG}) =………………………_____
7. $V_{WTSLOPE}$ — Percent of WAA with an altered water table slope…………………………….._____%
8. $V_{SURFCON}$ — Percent of adjacent stream reach with altered surface connections…………..._____%
9. V_{POND} — Percent of WAA that is capable of ponding water for extended periods………_____%
10. $V_{SOILINT}$ — Percent of WAA with altered soils…………………………………………….._____%
11. V_{HSOIL} — Hydric soil indicators (check one) Absence_____ Inundation_____ Saturation_____
12. V_{WTD} — Water table depth is………………………………………………………..._____inches
    Check data source: groundwater well___, redoximorphic features___, County Soil Survey___.
13. V_{CLAY} — Percent of WAA with altered clay content in soil profile…………………… _____%
14. $V_{CONDUCT}$ — Saturated hydraulic conductivity or Soil Profile Alteration (check one):
    No alteration to soils___, Top 6 in altered___, Entire profile altered___.

Sample variable 15 from a representative number of locations in the WAA using a 0.04 ha circular plot (11.3 m (37 ft) radius).

15. V_{TBA} — Tree basal area (average of 0.04 ha plot values on next line)……………….._____m^2/ha
    0.04 ha plots: 1____m^2/ha 2____m^2/ha 3____m^2/ha 4____m^2/ha

Sample variable 16 on two (2) 15 m transects partially within the 0.04 ha plot.

16. V_{WD} — Volume of woody debris (average of transect values on next line)…………_____m^3/ha
    Transect: 1____m^3/ha 2____m^3/ha 3____m^3/ha 4____m^3/ha

Figure 52. Field Data Sheet (Continued)

Sample variable 17 in two (2) 0.004 ha circular subplots (3.6 m (11.8 ft) radius) placed in representative locations of the 0.04 ha plot.

17. V_{SSD} Number of woody understory stems (average of 0.04 ha plot values on next line) ...._____stems/ha

0.04 ha plots: 1_____stems/ha 2_____stems/ha 3_____stems/ha 4____stems/ha

Sample variables 18-22 in four (4) m^2 subplots placed in representative locations of each quadrant of the 0.04 ha plot.

18. V_{GVC} Average cover of ground vegetation (average of 0.04 ha plot values on next line) ...._____%

Average of 0.04 ha plots sampled: 1____% 2____% 3____% 4____%

19. V_{OHOR} Average cover of "O" Horizon (average of 0.04 ha plot values on next line)_____%

Average of 0.04 ha plots sampled: 1____% 2____% 3____% 4____%

20. V_{AHOR} Average cover of "A" Horizon (average of 0.04 ha plot values on next line)_____%

Average of 0.04 ha plots sampled: 1____% 2____% 3____% 4____%

21. V_{OUS} Calculate the Floristic Quality Index of all trees and shrubs...................._____%

22. V_{DGCS} Concurrence with ground cover vegetation dominants (average of 0.04ha plot values on next line).._____%

Average of 0.04 ha plots sampled: 1____% 2____% 3____% 4____%

Figure 52. (Concluded)

Plot Worksheet: Low Gradient Riverine Wetlands in West Central Florida

Assessment Team:________________________
Project Name:____________________________ Plot Number:__________
Date:__________

13. V_{CLAY} Field Texture determination of clay content in soils.

Plot 1

Depth ______ Texture class clay % ______ = Depth X % Clay _______
Depth ______ Texture class clay % ______ = Depth X % Clay _______
Depth ______ Texture class clay% ______ = Depth X % Clay _______
Depth ______ Texture class clay% ______ = Depth X % Clay _______
Depth ______ Texture class clay% ______ = Depth X % Clay _______

Total Depth__20 inches = Total _______

Percent Clay = Total / Total Depth (20 inches) _______% Clay

Plot 2

Depth ______ Texture class clay % ______ = Depth X % Clay _______
Depth ______ Texture class clay % ______ = Depth X % Clay _______
Depth ___ Texture class clay %______ = Depth X % Clay _______
Depth ______ Texture class clay% ______ = Depth X % Clay _______
Depth ______ Texture class clay% ______ = Depth X % Clay _______

Total Depth__20 inches = Total _______

Percent Clay = Total / Total Depth (20 inches) _______% Clay

Plot 3

Depth ______ Texture class clay %______ = Depth X % Clay _______
Depth ______ Texture class clay % ______ = Depth X % Clay _______
Depth ______ Texture class clay% ______ = Depth X % Clay _______
Depth ______ Texture class clay% ______ = Depth X % Clay _______
Depth ______ Texture class clay% ______ = Depth X % Clay _______

Total Depth__20 inches = Total _______

Percent Clay = Total / Total Depth (20 inches) _______% Clay

Determine Weighted Average of Percent Clay (WAPC): Multiply % Wetland Area X % Clay

Percentage of Wetland area having ______ % Clay = ______X______=______

Percentage of Wetland area having ______ % Clay = ______X ______=______

Percentage of Wetland area having ______ % Clay = ______X ______=______

Percentage of Wetland area having ______ % Clay = ______X ______=______

Percentage of Wetland area having ______ % Clay = ______X ______=______

Percentage of Wetland area having ______ % Clay = ______X ______=______
Total ______X 100% = WAPC

Figure 53. Plot worksheet: Low-gradient riverine wetlands in west-central Florida (Sheet 1 of 5)

Plot Worksheet: Low Gradient Riverine Wetlands in West Central Florida

Assessment Team:______________________
Project Name:_________________________ Plot Number:__________
Date:__________

15. V_{TBA} Tree Basal Area. Record dbh (cm) of trees by species below, square dbh values (cm^2), multiply result by 0.000079 (m^2), and sum resulting values in shaded columns (m^2/0.04 ha). Record in space provided below worksheet , multiply by 25 (m^2/ha).

Species	dbh (cm)	dbh^2 (cm^2)	× 0.000079 (m^2/0.04 ha)	Species	dbh (cm)	dbh^2 (cm^2)	× 0.000079 (m^2/0.04 ha)

Sum of values from shaded columns above =_____ (m^2/0.04 ha) x 25 = _______m^2/ha.

Figure 53. (Sheet 2 of 5)

Plot Worksheet: Low Gradient Riverine Wetlands in West Central Florida

Assessment Team:____________________________
Project Name:________________________________ Plot Number:___________
Date:___________

16. V_{WD} Woody Debris Biomass

A. Record number of stems in size class 1 (0.6–2.5 cm / 0.25–1 in) along 2 - 50 ft (15 m) Transects for plots; Plot 1. Transect 1 _____ Transect 2_____ Total number of stems = ________
Plot 2. Transect 1 _____ Transect 2_____ Total number of stems = ________
Plot 3. Transect 1 _____ Transect 2_____ Total number of stems = ________

Size Class 1 tons/acre = 0.187 × total number of stems from 3 plots = ..._____tons/acre

B. Record number of stems in size class 2 (2.5–7.6cm / 1–3 in) along 2 - 50 ft (15 m) Transects for all plots; Plot 1. Transect 1 _____ Transect 2 _____Total number of stems = ________
Plot 2. Transect 1 _____ Transect 2 _____Total number of stems = ________
Plot 3. Transect 1 _____ Transect 2 _____Total number of stems = ________

Size Class 2 tons/acre = 0.892 × total number of stems =.................... ________ tons/acre

C. Record diameter of stems in size class 3 (>7.6 cm / >3 in) along 2 - 50 ft (15 m)Transects for all plots;

Plot 1: Transect 1	diameter	diameter^2	Transect 2	diameter	diameter^2
Stem 1 =	_______	_______	Stem 1 =	_______	_______
Stem 2 =	_______	_______	Stem 2 =	_______	_______
Stem 3 =	_______	_______	Stem 3 =	_______	_______
Stem 4 =	_______	_______	Stem 4 =	_______	_______
Stem 5 =	_______	_______	Stem 5 =	_______	_______
Stem 6 =	_______	_______	Stem 6 =	_______	_______
Stem 7 =	_______	_______	Stem 7 =	_______	_______
Stem 8 =	_______	_______	Stem 8 =	_______	_______
Total diameter^2		_______	Total diameter^2		_______

Plot 2: Transect 1	diameter	diameter^2	Transect 2	diameter	diameter^2
Stem 1 =	_______	_______	Stem 1 =	_______	_______
Stem 2 =	_______	_______	Stem 2 =	_______	_______
Stem 3 =	_______	_______	Stem 3 =	_______	_______
Stem 4 =	_______	_______	Stem 4 =	_______	_______
Stem 5 =	_______	_______	Stem 5 =	_______	_______
Stem 6 =	_______	_______	Stem 6 =	_______	_______
Stem 7 =	_______	_______	Stem 7 =	_______	_______
Stem 8 =	_______	_______	Stem 8 =	_______	_______

Figure 53. (Sheet 3 of 5)

Plot Worksheet: Low Gradient Riverine Wetlands in West Central Florida

Assessment Team:______________________
Project Name:______________________ Plot Number:__________
Date:__________

16. V_{WD} (continued)

Total diameter^2		______	Total diameter^2		______
Plot 3: Transect 1	diameter	diameter^2	Transect 2	diameter	diameter^2
Stem 1 =	______	______	Stem 1 =	______	______
Stem 2 =	______	______	Stem 2 =	______	______
Stem 3 =	______	______	Stem 3 =	______	______
Stem 4 =	______	______	Stem 4 =	______	______
Stem 5 =	______	______	Stem 5 =	______	______
Stem 6 =	______	______	Stem 6 =	______	______
Stem 7 =	______	______	Stem 7 =	______	______
Stem 8 =	______	______	Stem 8 =	______	______
Total diameter^2		______	Total diameter^2		______

Size Class 3 tons/acre = 0.0687 × Total diameter^2 of stems from both transects =______ tons/acre
Total tons/acre (sum of size classes 1–3 above) =.............................. ______ tons/acre
Cubic feet/acre = (32.05 × total tons/acre) / 0.058 = ... ______ cubic feet/acre
Cubic meters/ha = cubic feet/acre × 0.069 .... ______ cubic meters/ha

17. V_{SSD} Identify and tally woody understory stems from two 0.004 ha subplots in up to 3 plots, then average and multiply by 250:

Species	Tally	Species	Tally

Figure 53. (Sheet 4 of 5)

17. V_{SSD} (continued)

Species	Tally	Species	Tally

Plot 1: Subplot 1_____ Subplot 2_____......................................_____stems/ha
Plot 2: Subplot 1_____ Subplot 2_____......................................_____stems/ha
Plot 3: Subplot 1_____ Subplot 2_____......................................_____stems/ha

Average_____ x 250 = stems/ha

Figure 53. (Sheet 5 of 5)

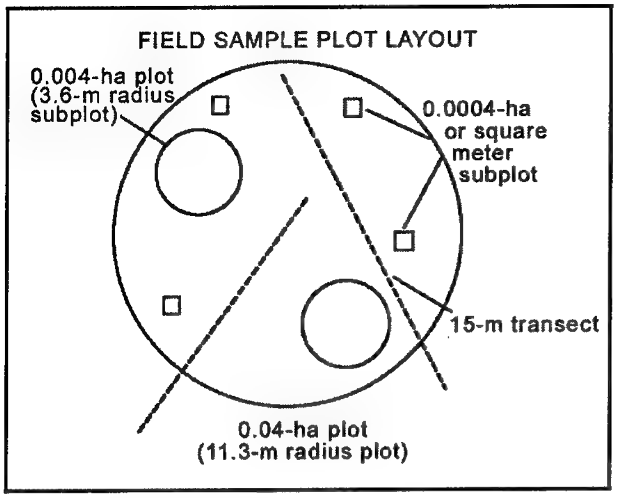

Figure 54. Circular sample plot and subplot dimensions and layouts for field sampling

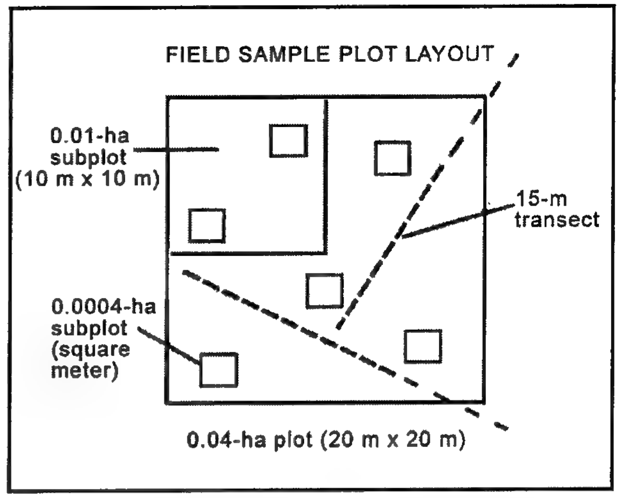

Figure 55. Square sample plot and subplot dimensions and layouts for field sampling

However, as the size and heterogeneity of the WAA increase, more sample plots are required to adequately represent the site.

Variable 15 is sampled using up to three 0.01-acre (0.04-ha) circular plots with a radius of 11.3 m or square plots 20 m on each side. Variable 16 is sampled along a minimum of two 50-ft (15-m) transects located randomly and at least partially in the 0.04-ha plot. Variable 17 is sampled using one 0.01-ha-square subplot placed in a representative portion of the 0.04-ha plot in up to three plots, or using two 0.004-ha subplots in one 0.04-ha plot. Variables 18-20 are sampled using four to six square-meter plots placed in representative portions of each quadrant of the 0.04-ha plot. Variable 21 is sampled by determining an FQI for the canopy and understory vegetative layers using basal area (V_{TDBH}), the quantative measure for the canopy layer and density (V_{SSD}), which determines abundance in the understory layer. The trees and shrubs are ranked, summed, and scored. Variable 22 is sampled by determining the dominant ground cover species from the area being assessed by summing the relative cover as a measure of abundance, beginning with the most abundant species in descending order until 50 percent dominance is reached, including species with ≥10 percent relative abundance. Percent concurrence is then calculated by comparing the list of dominant ground cover species to the list of dominant species found in reference standard wetlands.

For each location in the WAA where plot and transect data are collected (variables 15-21) a Plot Worksheet is filled out (Figure 53). Information from each Plot Worksheet is subsequently transferred to the Field Datasheet prior to determining the final value for each variable. For example, in calculating variable V_{TDBH} (#15) at each sampling location, begin by measuring the diameter at breast height of all trees in the 0.04-ha plot. Record these values by species in the table at the top of the Plot Worksheet, and then convert these values to m^2/0.04 ha and sum.

Carry the summed value down to the first line below the table, and convert to m^2/ ha. Transfer this value to the Field Datasheet where all the m^2/ ha values from the Plot Worksheet are summarized in the second line of the variable V_{TDBH} (#15). To determine the final value of variable V_{TDBH} (#15) average the m^2/ha values from each plot and transect sampling locations in the WAA. Complete instructions for collecting each variable in the field are provided in Appendix B along with a blank Plot Worksheet and Field Datasheet.

As in defining the WAA, there is clearly an element of subjectivity and practical limitations in determining the number of sample locations for collecting plot- and transect-based site-specific data. Experience has shown that the time required for two people to complete an assessment at a several-acre WAA where three plots are sampled is 2-4 hr. Training and experience will reduce the required time to the lower end of this range.

Analyze Field Data

The analysis of field data requires two steps. The first step is to transform the measure of each assessment variable into a variable subindex. This can be done using the graphs in Appendix B, or in a spreadsheet that has been set up to do the calculations automatically. The second step is to insert the variable subindices into the assessment model and calculate the FCI using the relationships defined in the assessment models. Again, this can be done manually or automatically using the automated worksheet.

Figure 56 shows an example of a spreadsheet that has been set up to do both steps of the analysis. The subindex for each variable is transferred into column D of the lower half of the spreadsheet to the right of the variable names. The calculated variable subindex is displayed in the fourth column of the lower half of the spreadsheet. The variable subindices are then used to calculate the FCI using the appropriate assessment model. The resulting FCI is displayed in the second column of the top half of the spreadsheet to the right of each function name. The spreadsheet format allows the user to instantly ascertain how a change in the field measure of a variable will affect the FCI of a particular function by simply entering a new variable subindex in the bottom half of the spreadsheet.

Apply the Results of the Assessment

Once the assessment and analysis phases are complete the results can be used to compare the same wetland assessment area at different points in time, comparing different wetland assessment areas at the same point in time, comparing different alternatives to a project, or comparing different hydrogeomorphic classes or subclasses, per Smith et al. (1995) and Davis (in preparation (Chapter 8)).

	FCI Calculation		
	West Central Peninsular Florida Riverine Regional Guidebook		
Eq.	Function	FCI	Expressions
1.	Temporarily Store Surface Water	0.00	$[(V_{FREQ} \times V_{STORE})^{1/2} \times (V_{ROUGH} + V_{FDC})/2]^{1/2}$
2.	Maintain Characteristic Subsurface Hydrology	0.00	$(V_{CONDUCT} \times V_{WTSLOPE})^{1/2}$
3.	Cycling of Nutrients	0.07	$[(V_{TDBH} + V_{UVB} + V_{GVB})/3 + (V_{AHOR} + V_{OHOR} + V_{WDB})/3]/2$
4.	Removal and Sequestration of Elements	0.39	$[(V_{FREQ} + V_{WTD})/2 \times (V_{CLAY} + V_{HSOIL} + V_{AHOR} + V_{OHOR})/4]^{1/2}$
5.	Retention of Particulates	0.00	$[(V_{FREQ} \times V_{STORE})^{1/2} \times (V_{ROUGH} + V_{FDC})/2]^{1/2}$
6.	Export Organic Carbon	0.22	$[(V_{FREQ} \times V_{SURFCON})^{1/2} \times (V_{OHOR} + V_{WDB})/2]^{1/2}$
7.	Maintain Characteristic Plant Community	0.26	$[(((V_{TDBH} + V_{UVB})/2 + (V_{OUS} + V_{DGCS})/2)/2 \times (V_{FREQ} + V_{WTD} + V_{SOILINT})/3)]^{1/2}$
8.	Provide Habitat for Wildlife	0.05	$[(((V_{FREQ} + V_{POND})/2 + (V_{AREA} + V_{CONNECT})/2) \times ((V_{UVB} + V_{OUS} + V_{TDBH} + (V_{WDB} + V_{OHOR})/2)/4)]^{1/2}$

	Variable Description	EQUATION VARIABLE	SITE MEASURE	UNITS Data	SUB INDEX
1.	Frequency of Overbank Flow	V_{FREQ}	1	years	1
2.	Floodplain Channel	V_{STORE}	0.00	%	0
3.	Floodplain Roughness	V_{ROUGH}	0.03	Observation	0.5
4.	Floodplain Discharge	V_{FPD}	0	Observation	0
5.	Extent of Ponding	V_{POND}	2	%	0.1
6.	Saturated Hydraulic Conductivity	$V_{CONDUCT}$	Normal	Observation	1
7.	Water Table Slope	$V_{WTSLOPE}$	0	Observation	0
8.	Tree Biomass	V_{TDBH}	3.93	m^2/ha	0.2
9.	Understory Vegetation Biomass	V_{UVB}	0.00	stems/ha	0
10.	Ground Vegetation Biomass	V_{GVB}	Very Dense	%	0.1
11.	Soil "A" Horizon	V_{AHOR}	0.00	%	0
12.	Soil "O" Horizon	V_{OHOR}	0.00	%	0
13.	Woody Debris Biomass	V_{WTD}	0.00	m^3/ha	0.1
14.	Hydric Soil Indicator	V_{HYDRIC}	Absent	Observation	0.1
15.	Surface Channel Connection	$V_{SURFCON}$	0.00	%	1
16.	Overstory and Understory Species	V_{OUS}	59.28	Index	0.1
17.	Soil Integrity	$V_{SOILINT}$	100.00	%	0
18.	Clay Content	V_{CLAY}	70.00	%	0.5
19.	Wetland Track Area	V_{AREA}	0.00	hectares	0
20.	Habitat Connection	$V_{CONNECT}$	0.00	%	0
21.	Water Table Depth	V_{WTD}	0.00	inches	1
22.	Dominant Ground Cover Species	V_{DGCS}	5.00	%Concurrence	0.1

Figure 56. FCI Worksheet

6 References

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Appendix A
Glossary

A Horizon—A mineral soil horizon at the soil surface or below an O horizon characterized by accumulation of humified organic matter intricately mixed with the mineral fraction.

Abiotic—Not living. Deposition of suspended sediments on floodplains an abiotic process.

Accretion—Vertical accumulation of sediments or organic matter. If organic matter is accumulating as a result of photosynthesis the process is biotic and may result in biogenic landscapes such as peat bogs.

Aerobic—Occurring in the presence of free molecular oxygen. Obligate aerobic bacteria cannot be active in the absence of oxygen.

Allelopathy—The influence or effect of one living plant upon another; refers to biochemical interaction between all types of plants. Its effect depends on a chemical compound being added to the environment.

Alluvial—Related to the overflow characteristics of rivers.

Aquifer, confined—An aquifer that is overlain by an aquiclude or aquitard and thus does not have a water surface in direct contact with the atmosphere.

Aquifer, surficial—The uppermost region of the aquifer that is near the land surface.

Assessment model—A simple model that defines the relationship between ecosystem and landscape scale variable and functional capacity of a wetland; the model is developed and calibrated using reference wetlands from a reference domain.

Assessment objective—The reason that an assessment of wetland functions is being conducted; assessment objectives normally fall into one of three categories: (1) documenting existing conditions; (2) comparing

different wetlands at the same point in time; and (3) comparing the same wetland at different points in time.

Assessment team (A-Team)—An interdisciplinary group of regional and local scientists responsible for classification of wetlands within a region, identification of reference wetlands, construction of assessment models, and calibration of assessment models.

Biogenic—derived or originating from living material, as peat.

Biogeochemical—The interaction and integration of biological and geochemical cycles.

Biotic—Refers to living processes or entities.

Blackwater stream—Streams common in the southeastern United States that have high concentrations of dissolved organic carbon and humic compounds, resulting in a darkly stained water.

Bog—A peatland that is nutrient poor because it lacks access to substantial quantities of mineral-rich water.

Bottomland—A general term that refers to floodplain wetlands.

Canopy—The top layer of the forest.

Channel—A natural stream or river, or an artificial feature such as a ditch or canal that exhibits features of bed and bank, and primarily conveys water unidirectionally downward.

Channelized flow—Flow that is confined to a channel in contrast to unchannelized (nonchannelized) flow or overland flow.

Denitrification—The microbially mediated heterotrophic process of converting nitrate or nitrite to either nitrous oxide or dinitrogen gas.

Depressional—A wetland geomorphic setting that occurs in depressions but usually at the headwaters of a local drainage. Consequently, surface flows are restricted.

Depressional wetland—A wetland located in a depression in the landscape so that the catchment area for surface runoff is generally small.

Detritus—Organic matter undergoing decomposition, with the attendant protists, protozoans, and other organisms that serve as food for detritus feeders.

Direct measure—a quantitative measure of an assessment model variable.

Discharge—The volume of flow per unit time, such as m^3/sec.

Edaphic (control)—The controls on plant-species distribution or function as a result of conditions in the soil in contrast to atmospheric controls.

Evapotranspiration—The combination of evaporation and transpiration expressed in the same units as precipitation.

Exotic—a nonindigenous species, or one introduced to this state, either purposefully or accidentally. A naturalized exotic that has escaped into the wild can *reproduce on its own* either sexually or asexually.

Facultative plants—Plants that usually occur (estimated probability 33 percent to 67 percent) in both wetlands and nonwetlands.

Facultative upland plants—Plants that occur sometimes (estimated probability 1 percent to 33 percent) in wetlands, but occur more often (estimated probability 67 percent to 99 percent) in nonwetlands.

Facultative wetland plants—Plants that occur usually (estimated probability 67 percent to 99 percent) in wetlands, but also occur (estimated probability 1 percent to 33 percent) in nonwetlands.

Fen—A peatland that is fed by groundwater; **poor fen**—a peatland that receives groundwater flow and achieves productivity intermediate between that of a rich fen and an ombrotrophic bog; **rich fen**—a highly productive peatland often dominated by grasses or trees in contrast with shrubs and mosses.

Floodplain—The land beside a river that receives overbank flooding when discharge exceeds channel capacity.

Fringe wetland—A wetland that is located near a large body of water, most typically the ocean, and receives frequent and regular two-way flow from astronomic tides or wind-driven water level fluctuations.

Function (ecosystem)—Processes that are necessary for the self-maintenance of an ecosystem such as primary production. nutrient cycling, decomposition, etc. The term is used primarily as a distinction from values. The term values is associated with society's perception of ecosystem functions. Functions occur in ecosystems regardless of whether or not they have values.

Functional assessment—The process by which the capacity of a wetland to perform a function is measured; this approach measures capacity using an assessment model to determine a function capacity index.

Functional capacity—The rate or magnitude at which a wetland ecosystem performs a function; functional capacity is dictated by characteristics

of the wetland ecosystem and the surrounding landscape, and interaction between the two.

Functional capacity index (FCI)—An index of the capacity of a wetland to perform a function relative to other wetlands within a regional wetland subclass in a reference domain. Functional capacity indices (FCIs) are by definition scaled from 0.0 to 1.0; an index of 1.0 indicates the wetland performs a function at the highest capacity, the level equivalent to a wetland under reference standard conditions in a reference domain; an index of 0.0 indicates the wetland does not perform the function at a measurable level, and will not recover the capacity to perform the function through natural processes.

Functional capacity unit (FCU)—Functional capacity index (FCI) multiplied by the size of the wetland assessment area (WAA) in acres, hectares, or other units of area.

Functional profile—Narrative or quantitative information on a wetland being assessed that describes the ecological significance of properties of water source, hydrodynamic, etc.

Geomorphic—A term that refers to the shape of the land surface.

Geomorphic setting—The location in a landscape, such as stream headwater locations, valley bottom depression, and coastal position.

Geomorphology—The study of earth's surface and its development.

Ground cover—All plants less than 4.5 ft (1.4 m) tall or have a DBH of less than 1 in. (25.4 mm) (vines are not considered); it is the lowermost of the three layers of vegetation.

Groundwater discharge—Flow originating from an aquifer that flows to the surface.

Hydraulic conductivity—A coefficient describing the rate at which water can move through a permeable medium.

Hydraulic gradient—The change in total head with a change in distance in a given direction. The direction is that which yields a maximum rate of decrease in head.

Hydric soil—A soil that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part.

Hydrodynamics—The motion of water that generally corresponds to its capacity to do work such as transport sediments, erode soils, flush pore waters in sediments, fluctuate vertically, etc. Velocities can vary within

each of three flow types—primarily vertical, primarily bidirectional and horizontal, and primarily unidirectional and horizontal. Vertical fluxes are driven by evapotranspiration and precipitation. Bidirectional flows are driven by astronomic tides and wind-driven seiches. Unidirectional flows are downslope movements that occur from seepage slopes and on floodplains.

Hydrogeomorphic wetland class—The highest level in the hydrogeomorphic wetland classification. There are five basic hydrogeomorphic wetland classes including depression, fringe, slope, riverine, and flat.

Hydrologic—dealing with the field of hydrology or the distribution and movement of water.

Hydroperiod—The depth, duration, seasonality, and frequency of flooding.

Indicators (of function)—Water chemistry, species composition, soil characteristics, or some other feature that allows one to infer or predict certain ecosystem functions or other conditions.

Interflow—The lateral movement of water in the unsaturated zone during and immediately after a precipitation event. The water moving as interflow discharges directly into a stream or lake or depression.

Inundation—The condition of water occurring above the surface. i.e., flooding.

Jurisdictional wetland—Areas that meet the soil, vegetation, and hydrologic criteria described in the *Corp of Engineers Wetlands Delineation Manual* (Environmental Laboratory 1987),[1] or its successor.

Kettles—Deep depressions in glaciated areas that resulted from the melting of an ice block that had been buried previously by glacial outwash. These small lakes may undergo hydrarch succession and fill with peat and become forested wetlands.

Kinetic energy —Energy of motion in contrast to stored or potential energy.

Landscape—Gross features of the land surface including but not limited to slope aspect, topographic variation, and position relative to other land forms.

Marsh—A wetland with emergent, herbaceous vegetation.

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1 References cited in this appendix are included in Chapter 6, References

Mitigation—Restoration or creation of a wetland to replace functional capacity that is lost as a result of project impacts.

Mitigation ratio—The ratio of the FCUs lost in a Wetland Assessment Area (WAA) to the FCUs gained in a mitigation wetland.

Mitigation wetland—A restored or created wetland that serves to replace functional capacity loss as a result of project impacts.

National Wetland Inventory—A program of the Fish and Wildlife Service that maps and categorizes wetlands of the United States. The categories used are those developed in the *Classification of Wetlands and Deep Water Habitats of the United States* (Cowardin et al. 1979).

Nitrate—The most oxidized form of nitrogen that can be used as an alternate electron acceptor in anaerobic respiration.

Nitrification—The microbial transformation from ammonium to nitrite and from nitrite to nitrate. It is an energy-yielding aerobic process.

Nonpoint source—Diffuse sources of nutrients or contaminants, often from agricultural and urbanized landscapes. They are in contrast to point sources, which are discharged from a pipe.

O Horizon—A layer with more than 12 to 18 percent organic C (by weight; 50 percent by volume). The form of the organic material may be recognizable plant parts (Oi) such as leaves, needles, twigs, moss, etc., partially decomposed plant debris (Oe), or totally decomposed organic material (Oa) such as muck.

Obligate upland plants—plants that occur rarely (estimated probability <1 percent) in wetlands, but occur almost always (estimated probability >99 percent) in nonwetlands under natural conditions.

Obligate wetland plants—plants that occur almost always (estimated probability >99 percent) in wetlands under natural conditions, but which also may occur rarely (estimated probability <1 percent) in nonwetlands.

Overbank flooding—Refers to excess flow to a floodplain when discharge of a stream exceeds channel capacity.

Overland flow—Water movement parallel with the soil surface.

pH—The negative log of the hydrogen ion concentration.

Palustrine—Nontidal wetlands where the salinity from ocean-derived salts is less than 5 ppt. Further modifiers are used by the National Wetland Inventory.

Partial wetland assessment area (PWAA)—A portion of a WAA that is identified *a priori*, or while applying the assessment procedure, because it is relatively homogeneous, and different from the rest of the WAA with respect to one or more model variables. The difference may occur naturally, or as a result of anthropogenic disturbance.

Physiognomy—The gross structure of a plant community resulting from the dominance of life forms such as trees, shrubs, graminoids, etc.

Piedmont—the steeper, rolling physiographic province formed at the base of mountains. Locally it is west of the Atlantic coastal plain and east of the mountains.

Pore water—Water that fills the interstices of soil or sediment.

Potential evapotranspiration (PET)—The amount of water that would be lost by evapotranspiration from natural vegetation in a particular climate if water was never limiting during the year.

ppt—Parts per thousand, units generally used for expressing salinity.

Primary production—The conversion of solar energy into organic matter by photosynthesis.

Project standards—Performance criteria and/or specifications used to guide the restoration or creation activities toward the project target; project standards should include and specify reasonable contingency measures if the project target is not being achieved.

Project target—The level of functioning identified for a restoration or creation project; conditions specified for the functioning are used to judge whether a project reaches the target and is developing toward site capacity.

Propagules—Reproductive structures, as the seeds or cuttings from plants.

Red flag features—Features of a wetland or the surrounding landscape to which special recognition or protection is assigned on the basis of objective criteria.

Redox—The potential difference, usually expressed in millivolts, between a platinum electrode and a reference electrode in a solution. The scale is especially useful for sediments that are devoid of oxygen because it allows an expression of reducing conditions beyond the scale of oxygen.

Reference domain—The geographic area from which reference wetlands are selected; may or may not include the entire geographic area in which a regional wetland subclass occurs.

Reference standards—conditions exhibited by a group of reference wetlands that correspond to the highest level of functioning (highest, sustainable level of functioning) across the suite of functions performed by the regional wetland subclass.

Reference standard sites—The sites within a reference wetland data set from which reference standards are developed; among all reference wetlands, reference standard sites are judged by an interdisciplinary team to have the highest level of functioning.

Reference wetlands—Wetland sites that encompass the variability of a regional wetland subclass in a reference domain; reference wetlands are used to establish the range of conditions of functional indices and establish reference standards.

Reference wetland subclass—Wetlands within a region that are similar based on hydrogeomorphic classification factors.

Region—A geographic area that is relatively homogenous with respect to large-scale factors such as climate and geology that may influence how wetlands function.

Regional wetland subclasses in Florida—Six hydrogeomorphic classes of wetlands have been subdivided into 37 subclasses for use in Florida based upon the diagnostic characteristics of vegetation, soils, and hydrologic criteria that are presented in Adamus et al. (1987) and Environmental Laboratory (1987).

Riparian—Pertaining to the boundary between water and land. Normally represents the streamside zone and the zone of influence of the stream toward the upland.

Saturated—In reference to soils, the condition in which all pore spaces are filled with water to the exclusion of a gaseous phase.

Seepage—Site where groundwater of a surficial aquifer discharges to the surface, often at the toe of a slope.

Seiche—Harmonic water level fluctuations in large lakes resulting from wind relaxation after a period of setup.

Setting, geomorphic—See **Geomorphic setting.**

Setup—The increase in water surface elevation downwind of a large body of water because of sustained winds.

Site potential—The highest level of functioning possible, given local constraints of disturbance history, land use, or other factors.

Succession—The predictable and orderly change in species composition over time at a particular location. Succession is sometimes called ecosystem development which places additional emphasis on abiotic components of change.

Swamp—An emergent wetland in which the uppermost stratum of vegetation is composed primarily of trees.

Topographic—A term referring to the slope and elevation of land.

Transport, overbank—Movement of water from the channel to the floodplain surface.

Upland—the land upslope from a wetland that lacks wetland characteristics.

Values—The rules that determine what people consider important; a measure that motivates people into activity.

Variable—An attribute or characteristic of a wetland ecosystem or the surrounding landscape that influences the capacity of a wetland to perform a function.

Variable condition—The condition of a variable as determined through quantitative or qualitative measure.

Variable Index—A measure of how an assessment model variable in a wetland compares to the reference standards of a regional wetland subclass in a reference domain.

Water quality—Descriptive or quantitative conditions of water, usually in reference to the physical, chemical, and biological properties, and usually from the perspective of society's use.

Water stress—A water deficit condition of plants that develops because plants are losing water by transpiration faster than they can take up water through their roots.

Water table—The surface of an unconfined water mass where the piezometric head equals atmospheric pressure.

Wetland assessment area (WAA)—The wetland area to which results of an assessment are applied.

Wetland functions—The normal activities or actions that occur in wetland ecosystems, or simply, the things that wetlands do.

Appendix B
Summaries and Forms for Field Use

This appendix contains the following summaries and example sheets:

Summary of Functions for Low-Gradient Riverine Wetlands

Function 1: Temporarily Store Surface Water

Definition

Temporary storage of surface water is defined as the capacity of a riverine wetland to temporarily store and convey floodwaters that inundate riverine wetlands during overbank flood events. Most of the water that is stored and conveyed originates from an adjacent stream channel. However, other potential sources of water include (a) precipitation; (b) surface water from adjacent uplands transported to the wetland via surface channels or overland flow; and (c) subsurface water from adjacent uplands transported to the wetland as interflow or shallow groundwater and discharging at the edge or interior of the floodplain. A potential independent quantitative measure for validating the functional index is the volume of water stored per unit area per unit time (m^3/ha/time) at a discharge that is equivalent to the average annual peak event.

Model variables - symbols - measures - units

Overbank Flood Frequency - V_{FREQ} - recurrence interval - years

Floodplain Storage Volume - V_{STORE} - floodplain width/channel width - unitless

Floodplain Discharge - V_{SLOPE} - change in channel features and floodplain slope - unitless

Floodplain Roughness - V_{ROUGH} - Manning's roughness coefficient n - unitless

Assessment model

$$FCI = \left[\left(V_{FREQ} \times V_{STORE} \right)^{1/2} \times \left(\frac{V_{SLOPE} + V_{ROUGH}}{2} \right) \right]^{1/2} \qquad \text{(B1)}$$

Function 2: Storage and Drainage of Subsurface Water

Definition

Maintain Characteristic Subsurface Hydrology is defined as the capacity of a low-gradient, blackwater stream bottomland hardwood forest wetland to store and drain subsurface water. Potential sources for subsurface water in riverine wetlands are direct precipitation, interflow (i.e., unsaturated subsurface flow), groundwater (i.e., saturated subsurface flow), and overbank flooding. A quantitative measurement of this function is the percentage of time during a year that a characteristic or historical average water depth is maintained.

Model variables - symbols - measures - units

Saturated Hydraulic Conductivity - $V_{SOILPERM}$ - soil permeability - inches/hour

Water Table Slope - $V_{WTSLOPE}$ - percent of area being assessed with an altered water table slope - unitless

Assessment model

$$FCI = (V_{SOILPERM} \times V_{WTSLOPE})^{1/2} \qquad \text{(B2)}$$

Function 3: Cycling of Nutrients

Definition

Patterns of nutrient cycling involve nutrient inputs to the system, storage of elements in biotic and abiotic pools, circulation and transformation of elements through living and dead organic matter, replenishment of nutrients through decomposition and weathering processes, and nutrient removals through leaching, gaseous, and other losses. In this biogeochemical approach, specific nutrients are not considered individually. Instead, all nutrients in general are considered by this function, which is quantified as the amount of nutrients processed per unit area (g/m^2) over a period of one year or less.

Model variables - symbols - measures - units

Tree Biomass - V_{TBA} - tree basal area - m^2/ha

Understory Vegetation Biomass - V_{SSD} - density of understory woody stems - stems/ha

Ground Vegetation Biomass - V_{GVC} - percent cover and height of ground vegetation - unitless

O Horizon Biomass - V_{OHOR} - percent cover of O soil horizon cover - unitless

A Horizon Biomass - V_{AHOR} - percent cover of A soil horizon cover - unitless

Woody Debris Biomass -V_{WD} - volume of woody debris - m^3/ha

Assessment model

$$FCI = \left[\frac{\left(\frac{V_{TBA} + V_{SSD} + V_{GVC}}{3} \right) + \left(\frac{V_{AHOR} + V_{OHOR} + V_{WD}}{3} \right)}{2} \right] \qquad \text{(B3)}$$

Function 4: Removal and Sequestering of Elements and Compounds

Definition

A riverine wetland has the capacity to remove and sequester imported nutrients, metals, and other elements introduced into the system. The term removal implies semipermanent loss of elements and compounds (e.g., deep burial in sediments) whereas the term sequestering implies relatively long-term accumulation of elements and compounds (e.g., storage in plant biomass). Elements include macronutrients such as nitrogen and phosphorus, and heavy metals such as zinc and chromium; compounds include pesticides. Mechanisms of removal and sequestering include sorption, chemical precipitation, hydrolysis, and similar processes. This function differs from the nutrient cycling function, which focuses on internal fluxes of nutrients within a period of one year or less. A quantitative measure of this function is the amount of elements and compounds removed and/or retained per unit time (i.e., g/m^2/year).

Model variables - symbols - measures - units

Overbank Flood Frequency - V_{FREQ} - recurrence interval - years

Water Table Depth - V_{WTD} - depth to seasonal high water table - inches

Soil Clay Content - V_{CLAY} - percent content of clay in upper soil horizon - unitless

Hydric Soil Indicators - V_{HSOIL} - inundation, saturation, or absence - unitless

O Horizon Biomass - V_{OHOR} - percent cover of O soil horizon cover - unitless

A Horizon Biomass - V_{AHOR} - percent cover of A soil horizon cover - unitless

Assessment model

$$FCI = \left[\left(\frac{V_{FREQ} + V_{WTD}}{2}\right) \times \left(\frac{V_{CLAY} + V_{HSOIL} + V_{AHOR} + V_{OHOR}}{4}\right)\right]^{1/2} \quad \text{(B4)}$$

Function 5: Retention of Particulates

Definition

Retention of particulates refers to the capacity of a wetland to physically remove and retain inorganic and organic particles 0.45 μm from the water column. Retention applies to particulates from both onsite and off-site sources. A quantitative measure of this function is the amount of particulates per unit area per unit time (i.e., $g/m^2/year$).

Model variables - symbols - measures - units

Overbank Flood Frequency - V_{FREQ} - recurrence interval - years

Floodplain Storage Volume - V_{STORE} - floodplain width/channel width - unitless

Floodplain Discharge - V_{SLOPE} - change in channel bed or floodplain slope - unitless

Floodplain Roughness - V_{ROUGH} - Manning's roughness coefficient n - unitless

Assessment model

$$FCI = \left[\left(V_{FREQ} \times V_{STORE}\right)^{1/2} \times \left(\frac{V_{SLOPE} + V_{ROUGH}}{2}\right)\right]^{1/2} \quad \text{(B5)}$$

Function 6: Export Organic Carbon

Definition

This function is defined as the capacity of the wetland to export dissolved and particulate organic carbon through processes including leaching, flushing, displacement and erosion. A quantitative measure of this function is the mass of carbon exported per unit area per unit time (g/m^2/year).

Model variables - symbols - measures - units

Overbank Flood Frequency - V_{FREQ} - recurrence interval - years

Surface Water Connections - $V_{SURFCON}$ - percent of the linear distance of altered stream reach - unitless

O Horizon Biomass - V_{OHOR} - percent cover of O soil horizon cover - unitless

Woody Debris Biomass - V_{WD} - volume of woody debris - m^3/ha

Assessment model

$$FCI = \left[\left(V_{FREQ} \times V_{SURFCON} \right)^{1/2} \times \left(\frac{V_{OHOR} + V_{WD}}{2} \right) \right]^{1/2} \qquad \text{(B6)}$$

Function 7: Maintain Characteristic Plant Community

Definition

This function is defined as the capacity of a riverine wetland to provide the environment necessary for a characteristic plant community to develop and be maintained. In assessing this function one must consider both the extant plant community as an indication of current conditions, and the physical factors that determine whether or not a characteristic plant community is likely to be maintained in the future. Vegetation description and statistical analysis used to define and measure the associations between both the environmental and biotic factors are multifaceted. Arranging vegetation samples to determine the relationship of species in terms of composition and environmental gradients can be accomplished through ordination methods (Kent and Coker 1995).[1] There are many ordination methods that can be used here. Some of these include the community classification method by TWINSPAN, an ordered two-way indicator species analysis (Hill 1979),

[1] References cited in this appendix are included in the References, Chapter 6.

detrended correspondence and reciprocal averaging of the DECORANA method (Hill and Gauch 1980), or canonical correspondence (CANOCO), an analysis that integrates and scores both species and environmental data (ter Braak 1994). Plants exhibit various degrees of habitat fidelity in response to their adaptive tolerance to disturbance. One method for measuring vegetation patterns as a reliable site indicator of both environmental and biotic factors is the Floristic Quality Assessment (Taft et al. 1997).

Model variables - symbols - measures - units

Tree Biomass - V_{TBA} - tree basal area - m^2/ha

Understory Vegetation Biomass - V_{SSD} - density of understory woody stems - stems/ha

Overstory and Understory Species Composition - V_{OUS} - Floristic Quality Index for all species in overstory and understory strata

Dominant Ground Cover Species - V_{DGCS} - Species diversity as a measurement of dominant ground cover vegetation.

Overbank Flood Frequency - V_{FREQ} - recurrence interval - years

Water Table Depth - V_{WTD} - depth (inches) to seasonal high water table

Soil Integrity - $V_{SOILINT}$ - percent of area with altered soils - unitless

Assessment model

$$FCI = \left\{ \left[\frac{\left(\frac{V_{TBA} + V_{SSD}}{2} \right) + \left(\frac{V_{OUS} + V_{DGCS}}{2} \right)}{2} \right] \times \left(\frac{V_{FREQ} + V_{WD} + V_{SOILINT}}{3} \right) \right\}^{1/2} \qquad \text{(B7)}$$

Function 8: Provide Habitat for Wildlife

Definition

This function is defined as the ability of a bottomland hardwood forest to support wildlife species that use these wetlands during some part of their life cycles. The focus of attention, however, is on terrestrial wildlife that reside primarily in this habitat for a significant portion of their life cycle. This equation is not based on maximizing species diversity, but maximizing the diversity of the suite of species thought to depend largely on this habitat type. The underlying assumption is that when habitat conditions favor these species, they also will be suitable to provide habitat for other species that use bottomland hardwood forests intermittently or for nonvertebrate species that are indicative of good bottomland hardwood forest habitat.

Model variables - symbols - measures - units

Overbank Flood Frequency - V_{FREQ} - recurrence interval - years

Extent of Ponding - V_{POND} - percentage of the wetland that is capable of retaining surface water - unitless

Wetland Tract Area - V_{AREA} - contiguous subclass type area - ha

Habitat Connectedness - $V_{CONNECT}$ - percentage of the perimeter that is connected to other native habitat - unitless

Understory Vegetation Biomass - V_{SSD} - density of understory woody stems - stems/ha

Overstory and Understory Species Composition - V_{OUS} - Floristic Quality Index for all species in overstory and understory strata

Tree Biomass - V_{TDBH} - tree basal area - m^2/ha

Woody Debris Biomass -V_{WDB} - volume of woody debris - m^3/ha

O Horizon Biomass - V_{OHOR} - percent cover of O soil horizon cover - unitless

Assessment model

$$FCI = \left[\frac{\left(\frac{V_{FREQ} + V_{POND}}{2}\right) + \left(\frac{V_{TRACT} + V_{CONNECT}}{2}\right)}{2} \times \frac{\left(\frac{V_{SSD} + V_{OUS} + V_{TBA}}{3}\right) + \left(\frac{V_{WD} + V_{OHOR}}{2}\right)}{2} \right]^{\frac{1}{2}} \quad 8)$$

Summary of Model Variable Definitions, Measure/Units, and Methods

1. Wetland Tract Area (V_{AREA})

Measure/Units: The area of wetland in hectares that is contiguous with the Wetland Assessment Area (WAA) and of the same regional wetland subclass.

Method: (1) Determine the size of the area of wetland of the same regional subclass that is contiguous with the assessment area using field reconnaissance, topographic maps, National Wetland Inventory maps (NWI), or aerial photography.

(2) Report the size of the wetland tract in hectares.

2. Habitat Connections ($V_{CONNECT}$)

Measure/Units: Calculated range from percentage of wetland perimeter habitat types: Suitable Habitat, Less Suitable Habitat, and Unsuitable Habitat.

Definitions of habitat types are as follows:

(1) Suitable habitats are other native natural habitats, whether forested or not.

(2) Habitats that are considered less suitable are unnatural vegetated habitats. These include habitats of mostly native plants that are not natural assemblages and habitats vegetated mostly by non-native species. Low-density suburban landscapes could be considered less suitable habitat if these landscapes were mostly vegetated in the manner described.

(3) Unsuitable habitats are areas mostly devoid of vegetation, such as recently cleared ground, roadways and parking lots, and areas of commercial development.

Table B1 provides an example of the calculation with 3,600 ft (1,097 m) of wetland tract perimeter as Suitable habitat, 1,000 ft (305 m) of wetland tract perimeter as Less Suitable habitat, and 500 ft (152 m) of wetland tract perimeter as Unsuitable habitat for a total of 5,100 ft (1,554 m) of wetland tract perimeter that is connected to the wetland. Measure it using the following procedure:

Method: (1) Measure the perimeter lengths of the bottomland hardwood forest perimeter that is adjacent to the three habitat types: Suitable habitat, Less Suitable habitat, and Unsuitable habitat.

(2) Divide the perimeter length of each habitat type separately by the total perimeter obtained by summing all three types.

(3) Multiply each type by 100 to obtain a percentage.

(4) Multiply each percentage by the assigned multipliers for each type: Suitable habitat = 1, Less suitable habitat = 0.7, Unsuitable habitat = 0.1

(5) Sum the total and report wetland tract perimeter as a percentage.

Table B1
Calculating Habitat Connections ($V_{CONNECT}$)

Forest Perimeter Type and Corresponding Variable Subindex	Perimeter, ft (m)	Determine Percent of Perimeter, Multiply by Variable Subindex	Calculated Percent
Suitable Habitat = 1	3,600 (1,097)	(3,600/5,100) × 100 = 70 percent 70 percent × 1	70
Less Suitable Habitat = 0.7	1,000 (305)	(1,000/5,100) × 100 = 20 percent 20 percent × 0.7	14
Unsuitable Habitat = 0.1	500 (152)	(500/5,100) × 100 = 10 percent 10 percent × 0.1	1
Total	5,100 (1,554)		
Calculated Percent of Connected Wetland Perimeter			85

3. Floodplain Discharge (V_{SLOPE})

Measure/Units: Changes in stream channel or floodplain slope.

Method:
(1) Determine if impacts or alterations to the channel or floodplain have been made.

(2) If the floodplain or floodplain slope has been altered by surface mining, fill, the placement of structures in the channel, or other slope altering activities, then a value of 0.1 is assigned.

(3) If channel dredging or straightening or other streambed or channel modifications have occurred, the value drops to 0.

(4) If no alterations have occurred to the floodplain or channel, then a value of 1.0 is assigned.

(5) Report floodplain discharge as no alterations, floodplain alterations, or channel alterations.

4. Floodplain Storage Volume (V_{STORE})

Measure/Units: The ratio of the floodplain width to channel width (i.e., floodplain with/channel width).

Method:
(1) Measure the width of the floodplain and the width of the channel using surveying equipment or pacing in the field. A crude estimate can be made using topographic maps or aerial photos, remembering that short distances on maps and photographs translate into long distances on the ground (i.e., the width of a section line on a 1:24,000 U.S. Geological Survey (USGS) topographic map represents about 30 ft (9 m) on the ground. The USGS fractional scale of 1:24,000 means that a distance of 1 *unit* on the map represents a distance of 24,000 of the same *units* on the surface of the earth. Therefore, 1 in. (2.5 cm) on the map equals

24,000 in. (60,960 cm) on the earth, or 1 cm on the map equals 24,000 cm on the earth). If USGS topographic maps are used to measure floodplain width, use of the metric scale will provide greater accuracy.

(2) Calculate the ratio by dividing the floodplain width by the channel width.

(3) Report the ratio of floodplain width to channel width as a unitless number.

5. Overbank Flood Frequency (V_{FREQ})

Measure/Units: Recurrence intervals in years.

Method: (1) Use one of the following methods to determining recurrence interval with the guidelines provided in Appendix C:

(a) Flood Frequency Analysis: Regional flood frequency calculations and regression equations developed by USGS, U.S. Department of Transportation, or U.S. Army Corps of Engineers (Bridges 1982; DelCharco and Hammett 2002).

(b) Numerical Modeling: Hydrologic models such as HEC-2 (U.S. Army Corps of Engineers 1981, 1982); HEC-RAS (U.S. Army Corps of Engineers 1997); HSPF (Bicknell et al. 1993); or other models are available as well.

(c) Local knowledge.

(d) Development of a Regional Dimensionless Rating Curve (Ainslie et al. 1999).

(2) Report recurrence interval in years.

6. Floodplain Roughness (V_{ROUGH})

Measure/Units: Manning's roughness coefficient n.

Method: (1) Determine n_{BASE}, the contribution to roughness of the soil surface. Arcement and Schneider (1989) suggest using 0.026, the value for firm sandy soil.

(2) Using the descriptions from Table B2, assign adjustment values to the roughness components of n_{TOPO}, n_{OBS}, and n_{VEG}.

(3) Sum the values of the roughness components to determine floodplain roughness. For example, Manning's roughness coefficient $n = n_{BASE} + n_{TOPO} + n_{OBS} + n_{VEG}$.

(4) Report Manning's roughness coefficient as a unitless number.

Table B2
Adjustment Values for Roughness Components Contributing to Manning's Roughness Coefficient n

Roughness Component	Adjustment to n Value	Description of Conditions
Topographic Relief (n_{TOPO})	0.0	Representative area is flat with essentially no microtopograhic relief (i.e., hummocks or holes) or macrotopographic relief (i.e., ridges or swales).
	0.005	Microtopographic relief (i.e., hummocks or holes) or macrotopographic relief (i.e., ridges or swales) cover 5-25 percent of a representative area
	0.02	Microtopographic relief (i.e., hummocks or holes) or macrotopographic relief (i.e., ridges or swales) cover >50 percent of a representative area
Obstructions (n_{OBS}) (includes coarse woody debris, stumps, debris deposits, exposed roots)	0.0	Obstructions occupy 1-5 percent of a representative cross-sectional area.
	0.002	Obstructions occupy 6-15 percent of a representative cross-sectional area.
	0.01	Obstructions occupy 16-50 percent of a representative cross-sectional area.
	0.05	Obstructions occupy >50 percent of a representative cross-sectional area.
Vegetation (n_{VEG})	0.0	No vegetation present.
	0.015	Representative area covered with herbaceous or shrubby vegetation where depth of flow exceeds height of vegetation by >2-3 times. Vegetation includes ground cover and/or sparse understory cover only.
	0.050	Representative area partially stocked with mature trees and covered with herbaceous or shrubby vegetation where depth of flow is at height of understory vegetation. Vegetation includes ground cover, dense woody undercover with sparse or no tree cover.
	0.1	Representative area fully stocked with mature trees and with sparse herbaceous ground cover and/or sparse woody understory vegetation.
	0.2	Representative area partially to fully stocked with trees and dense herbaceous cover and/or dense woody understory vegetation.

Note: Adapted from Arcement and Schneider (1989) and Ainslie et al. (1999).

7. Water Table Slope ($V_{WTSLOPE}$)

Measure/Units: The presence or absence of a changed elevation in water table slope.

Method: (1) Determine if the slope of the ground surface has been altered by ditching, dredging, channelization, wells, or other activities with the potential to modify the water table slope or, if the slope of the water table has not been altered.

(2) Report as presence or absence of an altered water table slope.

8. Surface Water Connections ($V_{SURFCON}$)

Measure/Units: The percent of the linear distance of stream reach to the WAA that has been altered is the measure of this variable.

Method: (1) Conduct a visual reconnaissance of the WAA and the adjacent stream reach. Estimate what percent of this stream reach has been modified with levees, sidecast materials, or other obstructions that reduce the exchange of surface water between the stream channel and the riverine wetland.

(2) Report percent of the linear distance of the stream reach that has been altered.

9. Extent of Ponding (V_{POND})

Measure/Units: Estimate percentage of WAA that is capable of ponding water in floodplain depressions.

Method: (1) Field reconnaissance, topographic maps, and aerial photographs can be used to estimate this variable. Features that are capable of holding water on a semipermanent basis such as abandoned channels and depressions within the floodplain are used to estimate this feature.

(2) Report the percentage of the WAA that is capable of ponding surface water.

10. Soil Integrity ($V_{SOILINT}$)

Measure/Units: The percent of the WAA with altered soils.

Method: (1) Determine if any of the soils in the area being assessed have been altered. In particular, look for alteration to a normal soil profile (for example, the absence of an A horizon).

(2) If no altered soils exist, assign the variable subindex a value of 1.0. This indicates that all of the soils in the assessment area are similar to soils in reference standard sites.

(3) If altered soils exist, determine what percent of the assessment area has soils that have been altered.

(4) Report the percent of the assessment area with altered soils.

11. Hydric Soil Indicators (V_{HSOIL})

Measure/Units: The presence or absence of hydric soil indicators is the measure of this variable.

Method: (1) Observe the top 6 in. (0.15 m) of sandy soil or 12 in. (0.3 m) of loamy or clayey soil, and determine if any indicators listed in National Resources Conservation Service (USDA NRCS 1998) are present.

(2) Record the indicator(s), if any. Report these indicators as inundation, saturation, or absence by choosing the most dominant indicators if any.

12. Water Table Depth (V_{WTD})

Measure/Units: Depth to the seasonal high water table in inches.

Method: (1) Determine the depth to the current seasonal high water table using, in order of accuracy and preference:

(a) Groundwater monitoring well data collected over several years.

(b) Redoximorphic features such as iron concentrations, reaction to *a, a'* dipyridyl, or the presence of a reduced soil matrix (Hurt, Watts, and Carlisle 2000; USDA NRCS 1998; Hurt and Brown 1995; Verpraskas 1994), remembering that some redoximorphic features reflect a soil that has been anaerobic at some time in the past, but that do not necessarily reflect current conditions.

(c) The presence of a seasonal high water table according to the Soil and Water Features Table in modern County Soil Surveys. In situations where the fluctuation of the water tables has been altered as a result of raising the land surface above the water table through the placement of fill, the installation of drainage ditches, or drawdown by water supply wells, the information in the Soil Survey is no longer useful. Under these circumstances the use of well data or redoximorphic features that indicate current conditions may be the only way to obtain the necessary information.

(2) Report depth to seasonal high water table in inches.

13. Soil Clay Content (V_{CLAY})

Measure/Units: The percentage of clay in the top 20 in. (0.5 m) of the soil profile from the WAA is used to quantify this variable.

Method: (1) Measure the soil particle size distribution in samples taken from the field.

(2) Estimate the percentage of clay from field texture determinations done by the "feel" method. Appendix C describes the procedure for estimating texture class by the feel method.

Based upon the soil texture class, determine the percentage of clay from the soil texture triangle. The soil texture triangle contains soil texture classes and the corresponding percentages of sand, silt, and clay that compose each class. The median value from the range of percent clay is used to calculate the weighted average. The median value of percent clay of each soil texture class is listed in Table B3.

(3) Calculate a weighted average of the percent clay by averaging the percent clay from each of the soil horizons to a depth of 20 in. (0.5 m). For example, if the A horizon occurs from a depth of 0-6 in. (0.15 m) and has 10 percent clay, and the B horizon occurs from a depth of 7-20 in. (0.18-0.5 m) and has 20 percent clay, then the weighted average of the percent clay for the top 20 in. (0.5 m) of the profile is

$$[(6 \times 10) + (14 \times 20)]/20 = 0.17 \text{ or } 17 \text{ percent} \qquad \text{(B9)}$$

If the clay content differs in several areas of the wetland, calculate a weighted average of the percent clay from each of these areas of the wetland. For example, if 70 percent of the wetland area has 10 percent clay, and 30 percent of the wetland area has 40 percent clay then the weighted average of the percent clay for that wetland is

$$[(10 \times 70) + (40 \times 30)] \times 100 = 19 \text{ percent} \qquad \text{(B10)}$$

(4) Report clay content as a percentage.

Table B3
Clay Content, percent, of Soil Texture Classes

Texture Class	Range of Clay Content, %	Median Value of Clay Content, %
Sand	0-10	5
Silt	0-13	7
Loamy sand	0-15	8
Sandy loam	0-20	10
Silt loam	0-27	14
Loam	7-27	17
Sandy clay loam	20-35	28
Silty clay loam	27-40	34
Clay loam	27-40	34
Sandy clay	35-55	45
Silty clay	40-60	50
Clay	40-100	70

14. Saturated Hydraulic Conductivity ($V_{SOILPERM}$)

Measure/Units: Soil Permeability in inches per hour.

Method: (1) Determine if soils in the area being assessed have been altered by agricultural activity, silvicultural activity, placement of fill, use of heavy equipment in construction projects or surface mining, or any other activities with the potential to alter effective soil permeability.

(2) If soils have been altered, select one of the following (*a* or *b*); otherwise skip to Step 3.

(*a*) Assign a value to soil permeability based on a representative number of field measurements of soil permeability. The number of measurements will depend on how variable and spatially heterogenous the effects of the alterations are on soil properties. Appendix C provides a procedure for measuring soil permeability in the field using a "pumping test" in which water is pumped quickly from a groundwater well and the rate at which the water level recovers is measured (Freeze and Cherry 1979).

(*b*) Assign a variable subindex based on the category of alteration that has occurred at the site using Table B4 (Note: in this particular situation no value is assigned to soil permeability; rather a variable subindex is assigned directly).

(3) If the soils have not been altered, select one of the two following alternatives.

(*a*) *Alternative 1:* Soil permeability can be measured in the field by the procedure of Freeze and Cherry (1979),

Table B4
Soil Permeability Values, in./hr, for Silvicultural, Agricultural, Mining, and Other Soil Alterations

Alteration Category	"Typical" Soil Permeability after Alteration	Average Depth of Alteration Effects	Variable Subindex
Activities that compact surface layers and reduce permeability to a depth of about 6 in. (0.15 m) (Aust 1994), such as with silviculture.	Highly variable and spatially heterogeneous	Top 6 in. (0.15 m) of soil profile	0.5
Activities, such as agricultural tillage or pavers, etc., that create some surface compaction as well as generally decreasing the average size of pore spaces. These activities decrease the ability of water to move through the soil to a depth of about 6 in. (0.15 m) (Drees et al. 1994).	Highly variable and spatially heterogeneous	Top 6 in. (0.15 m) of soil profile	0.5
Compaction resulting from large equipment over the soil surface, cover of soil surface with pavement or fill material, or excavation and subsequent replacement of heterogeneous materials such as with construction activities/surface mining.	Highly variable and spatially heterogeneous	Entire soil profile	0.1

called the pumping test, by removing water from or adding it to a well and observing the rate at which water level changes in the well. Appendix C provides a procedure for application of the pumping test. Details of this technique can also be found in most groundwater texts. The number of field measures will depend on how variable and spatially heterogenous the soils are onsite.

(*b*) *Alternative 2:* An alternative method is to assign a value to soil permeability by calculating the weighted average of median soil permeability to a depth of 20 in. (0.5 m). Values for soil permeability can be obtained from county soil surveys. Permeabilities and weighted average permeabilites for soil series associated with bottomland hardwood forests in the reference domain (sixteen counties within the Southwest Florida Water Management District) are tabulated in Table B5.

(*c*) The following example demonstrates how each weighted average permeability was determined. The Bradenton series has a median soil permeability of 13 in./hr (0.3 m/hr) for 0-13 in. (0.3 m) depth, and a median soil permeability value of 1.3 in./hr (33 mm/hr) from

Table B5
Permeability/Saturated Hydraulic Conductivity by Soil Layer (Upper 20 in. (0.5 m)) for Hydric Soil Series Associated with Bottomland Hardwood Forests in Peninsular Florida

Soil Series	Depth, in.	Range of Soil Permeability in./hr	Weighted Average Soil Permeability for Upper 20 in. (0.5 m) (in./hr)
Anclote	0-20	6.0-20	13
Astor	0-20	6.0-20	13
Basinger	0-20	6.0-20	13
Bluff	0-13; >13-20	0.2-0.6; 0.06-0.2	0.3
Bradenton	0-13; >13-20	6.0-20; 0.6-2.0	9
Chobee	0-15; >15-20	2.0-6.0; <0.2	3
Delray	0-20	6.0-20	13
Felda	0-20	6.0-20	13
Floridana	0-20	6.0-20	13
Holopaw	0-20	6.0-20	13
Iberia	0-20	<0.06	<0.1
Malabar	0-20	6.0-20	13
Manatee	0-10; >10-20	2.0-6.3; 0.63-2.0	3
Nittaw	0-6; >6-20	0.6-6.0; 0.06-0.2	1
Pineda	0-20	6.0-20	13
Placid	0-20	6.0-20	13
Pompano	0-20	>20	>20
Wabasso	0–20	6.0-20	13
Winder	0–14; >14–17; >17–20	6.0-20; 0.2-0.6; <0.2	9

Note: To convert inches to meters, multiply by 0.0254.

13- to 20-in. (0.3- to 0.5-m) depth. The weighted average of the median soil permeability for the top 20 in. (0.5 m) is

$$[(13 \times 13) + (7 \times 1.3)]/20 = 8.9 \quad \text{(B11)}$$

(4) Report saturated hydraulic conductivity as alteration of soil in depth or unaltered soils.

15. Tree Basal Area (V_{TBA})

Measure/Units: The basal area converted to a per-hectare basis for canopy layer trees with diameters greater than 10 cm is the measure of this variable.

Method: (1) Measure the dbh in cm of all trees in a circular, or square, 0.04-ha (11.3-m radius or 20-m^2) sampling unit hereafter called a plot.

(2) Convert each of the diameter measurements to area, sum them, and convert to square meters. For example, if three trees with diameters of 20 cm, 35 cm, and 22 cm were present in the plot, the conversion to square meters would be as follows: remembering that the diameter of a circle D can be converted to area A using the relationship $A = \frac{1}{4}\pi D^2$, it follows that $\frac{1}{4}\pi 20^2 = 314$ cm^2, $\frac{1}{4}\pi 35^2 =$ 962 cm^2, $\frac{1}{4}\pi 22^2 = 380$ cm^2. Summing these values gives $314 + 962 + 380 = 1{,}656$ cm^2 and converting to square meters by multiplying by 0.0001 gives 1656 cm^2 $\times$ 0.0001 = 0.17 m^2.

(3) If multiple 0.04-ha plots are sampled, average the results from all plots.

(4) Convert the results to a per-hectare basis by multiplying by 25, since there are 25 0.04-ha plots in a hectare. For example, if the average value from all the sampled plots is 0.17 m^2, then 0.17 m^2 $\times$ 25 = 4.3 m^2 ha^{-1}.

(5) Report tree basal area in m^2 ha^{-1}.

16. Woody Debris Biomass (V_{WD})

Measure/Units: Volume of woody debris in cubic meters per hectare is the measure of this variable.

Methods: (1) Count the number of stems that intersect a vertical plane along a minimum of two 50-ft (15-m) transects located randomly, and at least partially inside each 0.04-ha plot. Count the number of stems that intersect the vertical in each of three different size classes along the transect

distances. In addition to counting the number of stems, measure the diameter for all stems in the >3-in.- (76-mm-) diam class.

(2) Convert stem counts for each size class to tons per acre using the following formulas:

$$\text{tons/acre} = \frac{\left(11.64 \times n \times d^2 \times s \times a \times C\right)}{N \times l} \qquad \text{(B12)}$$

where:

- n = total number of intersections (i.e., counts) on all transects
- d^2 = squared average diameter for each size class
- s = specific gravity (Birdsey (1992) suggests a value of 0.58)
- a = nonhorizontal angle correction (suggested value 1.13)
- C = slope correction factor (suggested value 1.0 since slopes in southeastern forested floodplains are negligible)
- N = number of transects
- l = length of transect in feet

For stems in the >3-in. (76-mm) size class, use the following formula:

$$\text{tons/acre} = \frac{\left(11.64 \times \sum d^2 \times s \times a \times C\right)}{N \times l} \qquad \text{(B13)}$$

where $\sum d^2$ is the squared average diameter for each size class.

When large areas with many different tree species are being inventoried, it is practical to use composite values and approximations for diameters, specific gravities, and non-horizontal angle corrections. For example, if composite average diameters, composite average nonhorizontal correction factors, and best approximations are used for the southeast, the preceding value for stems in the 0.25- to ≤1.0-in. (6- to ≤25-mm) size class simplifies to:

$$\text{tons/acre} = \frac{(2.24n)}{N \times l} \qquad \text{(B14)}$$

For stems in the >1.0- to ≤3.0-in. (>25- to ≤76-mm) size class the formula simplifies to:

$$\text{tons/acre} = \frac{(21.4n)}{N \times l} \qquad \text{(B15)}$$

For stems in the ≥3.0-in. (≥76-mm) size class the formula simplifies to:

$$\text{tons/acre} = \frac{\left[6.87\left(\sum d^2\right)\right]}{N \times l} \qquad \text{(B16)}$$

(3) Sum the tons per acre for the three size classes and convert to cubic feet per acre:

$$\text{cubic feet/acre} = \frac{(\text{tons/acre} \times 32.05)}{0.58} \qquad \text{(B17)}$$

(4) Convert cubic feet per acre to cubic meters per acre by multiplying cubic feet per acre by 0.072.

(5) Report woody debris volume in m^3/ha.

17. Understory Vegetation Biomass (V_{SSD})

Measure/Units: Understory stem density in number of stems per hectare.

Methods: (1) Identify the species and count the stems of understory vegetation in two 0.004-ha (3.6-m radius or a 10-m^2) sampling units (hereafter called subplots) located in representative portions from two quadrants of each 0.04-ha plot. Sample using one 0.004-ha subplot for each 0.04-ha plot if the stand is in an early stage of succession and a high density of stems makes additional sampling impractical.

(2) If 0.004-ha subplots are used, average the results and multiply by 10 to serve as the value for each 0.04-ha plot.

(3) If multiple 0.04-ha plots are sampled, average the results from all 0.04-ha plots.

(4) Convert the results to a per-hectare basis by multiplying by 25. For example, if the average of 0.04-ha plots is 23 stems, then 23 × 25= 575 stems/ha.

(5) Report shrub and sapling density as stems/ha.

18. Ground Vegetation Biomass (V_{GVC})

Measure/Units: Percent cover of ground vegetation

Methods: There are two alternatives for measuring percent ground vegetation biomass:

(1) Alternative one:
   (*a*) Visually estimate the percentage of ground surface that is covered by ground vegetation in the WAA by mentally projecting the leaves and stems of ground vegetation to the ground surface. Walking through the WAA and viewing the ground cover vegetation from above is suggested as this provides a more accurate and precise measure of cover due to vegetation stratification and multiple layering.
   (*b*) Report ground vegetation cover as a percent.

(2) Alternative two.
   (*a*) Visually estimate the percentage of the ground surface that is covered by ground vegetation by mentally projecting the leaves and stems of ground vegetation to the ground surface in each of the six m^2 sampling units, hereafter called subplots, placed in representative portions of each quadrant of a 0.04-ha plot. The number of 0.04-ha plots required to adequately characterize an area will depend on its size and heterogeneity. The chapter "Assessment Protocol" provides guidance for determining the number and layout of sample points and sampling units.
   (*b*) Average the values from the six m^2 subplots.
   (*c*) If multiple 0.04-ha plots are sampled, average the results from all the 0.04-ha plots.
   (*d*) Report ground vegetation cover as a percent.

19. "O" Horizon Biomass (V_{OHOR})

Measure/Units: Percent cover of the O soil horizon.

Methods: (1) Visually estimate the percentage of the ground surface that is covered by an O horizon in each of four 1-m^2 subplots placed in representative portions of each quadrant of a 0.04-ha plot. The number of 0.04-ha plots required to adequately characterize the area being assessed will depend on its size and heterogeneity. The chapter "Assessment Protocol" provides guidance for determining the number and layout of sampling points and sampling units.

(2) Average the results from the 1-m^2 subplots within each 0.04-ha plot.

(3) If multiple 0.04-ha plots were sampled, average the results from these plots.

(4) Report O horizon cover as a percent.

20. A Horizon Biomass (V_{AHOR})

Measure/Units: Percent cover of the A soil horizon.

Methods: (1) Estimate the percentage of the mineral soil within the top 15 cm (6 in.) of the ground surface that qualifies as an A horizon by making a number of soil observations in each of four 1-m^2 subplots placed in representative portions of each quadrant of a 0.04-ha plot. For instance, if in each subplot 12 soil plugs are taken and 6 show the presence of a 7.5-cm-(3-in.-) thick A horizon, the value of the A horizon cover is $(6/12) \times 100 = 50$ percent. The number of 0.04-ha plots required to adequately characterize the area being assessed will depend on its size and heterogeneity. The chapter "Assessment Protocol" provides guidance for determining the number and layout of sampling points and sampling units.

(2) Average the results from the 1-m^2 subplots within each 0.04-ha plot.

(3) If multiple 0.04-ha plots were sampled, average the results from these plots.

(4) Report A horizon cover as a percent.

21. Overstory and Understory Species Composition (V_{OUS})

Measure/Units: Floristic Quality Index (FQI) for all species in overstory and understory vegetation strata.

Methods: (1) Identify species in the overstory and understory vegetative layers. Use tree basal area to determine abundance in the canopy stratum and use density to determine abundance in the understory stratum. Sampling during the dormant season may require a high degree of proficiency in identifying tree bark or dead plant parts. Users who do not feel confident in identifying plant species in all strata should get help with plant identification.

(2) Table B6 and the following listing provide the species ranking for each vegetation strata. (Species identified at the site but not occurring on this list can be added and ranked after consulting floristic manuals or publications along with confirmation by experienced ecologists or botanists.) Exotic species are listed in Table B7 and following.

(3) Calculate the FQI using the automated sheet or by the following explanation. A ranking from 1-5 has been assigned to each species in Tables B6 and B7 and the following. The rank of 5 has been assigned to species having the highest fidelity to bottomland hardwood forests. Lower ranks have been assigned to species having lower fidelity

to bottomland hardwood forests with the tendency to occur in many habitat types to those species that are invasive. This index is termed the coefficient of conservation (COC). The categories for species rankings consist of the following:

Ranking	Description
1	Taxa that are adapted to severe disturbance, in particular anthropogenic and all invasive exotic species, generally considered ruderal-invasive species.
2	Taxa associated with more stable though degraded habitat, generally considered ruderal-competitive nuisance species.
3	Taxa having a high consistency of occurrence within several community types that can persist under moderate disturbance. Increases in the intensity and frequency of disturbance may result in an increase in population size.
4	Taxa associated mostly with natural areas but can persist where habitat has been somewhat altered or degraded. Increases in the intensity or frequency of disturbance may result in reduced population size, may be subject to local extirpation, or may highly increase in population size.
5	Taxa exhibiting a high degree of fidelity to a narrow range of synecological parameters. Species within this category are restricted to relatively intact natural areas.

(4) To allow greater sensitivity in interpretation of floristic integrity across the range of variation within a HGM subclass, quantitative data are needed. This may be required in HGM subclasses encompassing several seral stages or those subject to fluctuations in composition diversity or community structure based on intra- or interannual climatic cycles. Also, a ranking category with species having high COC values at low abundance can result in sites having the same COC values but different FQI's or sites having the same FQI's can have different COC values. The FQI algorithm is then indicated by:

$$FQRWj = \frac{\sum_{i=1}^{n} C_{ij} * A_{ij}}{\sum_{i=1}^{n} A_{ij}} \qquad \text{(B18)}$$

where

$FQRWj$ = Floristic Quality relative weighted score for stand j

C_{ij} = Ranking categories for species i in stand j

A_{ij} = Abundance of species i per ranking category in stand j

n = number of species

$\sum_{i=1}^{n}$ = summation across all species in the stand

(5) Combine the sum of basal area for each ranking COC category from all overstory species (i.e., COC Ranks 1 through 5, combine the sum for all 1's, combine the sum for all 2's, etc.).

(6) Combine the sum of density for each ranking COC category from all understory species.

(7) Calculate the relative percentage of the basal area or density for each of the five COC categories based on the total percentage of basal area or density of all species for the site. A sum of the percentages should yield 100 percent.

(8) Multiply the percentage for each summed COC category ranking by the following factors:

COC Rank	Factor	Based on Reference Standards
1	0	Invasive exotics receive no value
2	0.1	
3	0.3	
4	0.8	Use this multiplicative factor if the percentage is <40 percent
4	0.1	Use this multiplicative factor if the percentage is >40 percent
5	1.0	

(9) The maximum resultant scores for each vegetative layer is 100 with a maximum score of 200 for both layers combined.

(10) Report Plant Species Composition as a combined score.

Table B6
Species by Strata Occurring in West-Central Peninsular Florida Low-Gradient Riverine Wetlands

Sp#	Tree Species	Common Name	COC
		Overstory Species	
1	*Acer rubrum*	Red maple	4
2	*Carpinus caroliniana*	American hornbean/Muscle wood	5
3	*Carya aquatica*	Water hickory	5
4	*Carya glabra*	Sweet hickory	5
5	*Celtis laevigata*	Sugarberry	4
6	*Citrus* sp.	Wild citrus	2
7	*Cornus foemina*	Swamp dogwood	5
8	*Diospyros virginiana*	Common persimmon	5
9	*Fraxinus caroliniana*	Carolina ash/Pop ash	5
10	*Gleditsia aquatica*	Water locust	5
11	*Gordonia lasianthus*	Loblolly bay	4
12	*Ilex opaca*	American holly	5
13	*Juniperus silicicola*	Red cedar	4
14	*Liquidambar styraciflua*	Sweet gum	5
15	*Magnolia virginiana*	Sweet bay	5
16	*Morus rubra*	Red mulberry	5
17	*Nyssa biflora*	Water tupelo	5
18	*Persea palustris*	Swamp bay	5
19	*Prunus serotina*	Cherry laurel	2
20	*Quercus laurifolia*	Laurel oak	5
21	*Quercus nigra*	Water oak	5
22	*Quercus virginiana*	Live oak	5
23	*Schinus terebinthifolius*	Brazilian pepper	1
24	*Taxodium distichum*	Bald cypress	5
25	*Tilia americana*	Basswood	5
26	*Ulmus americana*	American elm	5
		Understory Species	
1	*Acer rubrum*	Red maple	4
2	*Bumelia reclinata*	Florida Bumelia	5
3	*Carpinus caroliniana*	American hornbean/Muscle wood	5
4	*Carya aquatica*	Water hickory	5
5	*Carya glabra*	Sweet hickory	5
6	*Celtis laevigata*	Sugarberry	4
7	*Cephalanthus occidentalis*	Button bush	5
8	*Citrus* sp.	Wild citrus	2
9	*Cornus foemina*	Swamp dogwood	5
10	*Crataegus marshallii*	Parsley haw	5

(Sheet 1 of 4)

Table B6 (Continued)

Sp#	Species Name	Common Name	COC
		Understory Species (Concluded)	
11	*Diospyros virginiana*	Common persimmon	5
12	*Fraxinus caroliniana*	Carolina ash/Pop ash	5
13	*Gleditsia aquatica*	Water locust	5
14	*Gordonia lasianthus*	Loblolly bay	4
15	*Ilex cassine*	Dahoon holly	5
16	*Ilex opaca*	American holly	5
17	*Itea virginica*	Virginia willow	5
18	*Juniperus silicicola*	Red cedar	4
19	*Liguidambar styraciflua*	Sweet gum	5
20	*Magnolia virginiana*	Sweet bay	5
21	*Morus rubra*	Red mulberry	5
22	*Myrica cerifera*	Wax myrtle	3
23	*Nyssa biflora*	Water tupelo	5
24	*Persea palustris*	Swamp bay	5
25	*Prunus serotina*	Cherry laurel	2
26	*Quercus laurifolia*	Laurel oak	5
27	*Quercus nigra*	Water oak	5
28	*Quercus virginiana*	Live oak	5
29	*Sabal minor*	Dwarf palmetto	5
30	*Sabal palmetto*	Cabbage palm	4
31	*Salix caroliniana*	Carolina willow	2
32	*Schinus terebinthifolius*	Brazilian pepper	1
33	*Serenoa repens*	Saw palmetto	3
34	*Taxodium distichum*	Bald cypress	5
35	*Tilia americana*	Basswood	5
36	*Ulmus americana*	American elm	5
37	*Vaccinium arboreum*	Farkleberry/Sparkleberry	4
38	*Vaccinum corymbosum*	Highbush blueberry	4
39	*Viburnum obovatum*	Walter viburnum	5
		Dominant Ground Cover Species	
1	*Ampelopsis arborea*	Pepper-vine	
2	*Arisaema triphyllum*	Swamp jack-in-the-pulpit	
3	*Asclepius perennis*	Aquatic milkweed	
4	*Aster carolinianus*	Climbing aster	
5	*Aster elliottii*	Elliott's aster	
6	*Bacopa monnieri*	Coastal water-hyssop	
7	*Blechnum serrulatum*	Swamp fern	
8	*Boehmeria cylindrica*	Small-spike false-nettle	

(Sheet 2 of 4)

Table B6 (Continued)		
Sp#	**Species Name**	**Common Name**
	Dominant Ground Cover Species (Continued)	
9	*Campsis radicans*	Trumpet-creeper
10	*Carex elliottii*	Elliott's sedge
11	*Carex gigantea*	Large sedge
12	*Carex longii*	Greenish-white sedge
13	*Carex lupuliformis*	False hop sedge
14	*Carex typhina*	Cat-tail sedge
15	*Carpinus caroliniana*	American hornbeam
16	*Chasmanthium nitidum*	Shiny spikegrass
17	*Clematis crispa*	Swamp virgin's-bower
18	*Commelina diffusa*	Spreading dayflower
19	*Conoclinium coelestinum*	Mistflower
20	*Crinum americanum*	Southern swamplily
21	*Dichanthelium ensifolium*	
22	*Dichondra caroliniensis*	Pony-foot
23	*Dyschoriste humistrata*	Swamp dyschoriste
24	*Elytraria caroliniensis*	Carolina scaly-stem
25	*Epidendrum conopseum*	
26	*Erechtites hieracifolia*	Fireweed
27	*Habeneria repens*	Rein orchid
28	*Hydrocotyl umbellata*	Many-flower penny-wort
29	*Hymenocallis* spp.	Spider-Lily
30	*Hypericum hypericoides*	St. Andrew's cross
31	*Hypoxis leptocarpa*	Yellow stargrass
32	*Iris virginica*	Virginia blueflag
33	*Lactuca floridana*	Woodland lettuce
34	*Ludwigia repens*	Creeping seedbox
35	*Lycopus rubellus*	Taper-leaf bugleweed
36	*Mecardonia acuminata*	Purple mecardonia
37	*Mitchella repens*	Partridge-berry
38	*Oplismenus setarius*	Basket grass
39	*Orontium aquaticum*	Golden club
40	*Osmunda cinnamomea*	Cinnamon fern
41	*Osmunda regalis*	Royal fern
42	*Oxalis corniculata*	Creeping woodsorrel
43	*Panicum commutatum*	Variable witchgrass
44	*Panicum dichotomiflorum*	Fall panic grass
45	*Panicum dichotomum*	Cypress witchgrass
46	*Panicum gymnocarpon*	Savannah panic grass
47	*Panicum rigidulum*	Red-top panic grass
48	*Parietaria floridana*	Florida pellitory
		(Sheet 3 of 4)

Table B6 (Concluded)

Sp#	Species Name	Common Name
	Dominant Ground Cover Species (Concluded)	
49	*Parthenocissus quinquefolia*	Virginia creeper
50	*Phanopyrum gymnocarpon*	Savannah panic grass
51	*Physostegia leptophylla*	Slender-leaf dragon-head
52	*Physotegia purpea*	Purple dragon-head
53	*Pluchea foetida*	Stinking camphor-weed
54	*Pluchea odorata*	Shrubby camphor-weed
55	*Polygonum setaceum*	
56	*Psychotria nervosa*	Shiny wild coffee
57	*Psychotria sulzneri*	Dull wild coffee
58	Rhus copallinum	Winged sumac
59	*Rhynchospora caduca*	Falling beakrush
60	*Rhynchospora miliacea*	Millet beakrush
61	*Rhynchospora* spp.	
62	*Ruellia caroliniensis*	Wild-petunia
63	*Sabatia calycina*	Coast rose-gentian
64	*Samolus parviflorus*	Water pimpemel
65	*Saururus cernuus*	Lizard's tail
66	*Senecio anonymus*	Small's groundsel
67	*Senecio glabellus*	Butterweed
68	*Smilax bona-nox*	Saw greenbrier
69	*Smilax laurifolia*	
70	*Thelypteris dentata*	Downy maiden fern
71	*Thelypteris hispidula*	Hairy tri-vein fern
72	*Thelypteris interrupta*	Willdenow's maiden fern
73	*Thelypteris palustris*	Marsh fern
74	*Toxicodendron radicans*	Poison ivy
75	*Viola affinis*	Leconte's violet
76	*Vitis munsoniana*	Muscadine grape
77	*Woodwardia aereolata*	Netted chainfern
78	*Woodwardia virginica*	Virginia chainfern
		(Sheet 4 of 4)

Table B7
Florida Exotic Pest Plant Council's List of Florida's Most Invasive Species

Scientific Name	Common Name	FLEPPC Rank	Government Listed	COC Rank
Category I – Species that are invading and disrupting native plant communities in Florida. *This definition does not rely on the economic severity or geographic range of the problem, but on the documented ecological damage caused.*				
Abrus precatorius	Rosary pea	I		1
Acacia auriculiformis	Earleaf acacia	I		1
Albizia julibrissin	Mimosa, silk tree	I		1
Albizia lebbeck	Woman's tongue	I		1
Ardisia crenata (=*A. crenulata*)	Coral ardisia	I		1
Ardisia elliptica (=*A. humilis*)	Shoebutton ardisia	I		1
Asparagus densiflorus	Asparagus-fern	I		1
Bauhinia variegata	Orchid tree	I		1
Bischofia javanica	Bischofia	I		1
Calophyllum antillanum (=*C. calaba; C. inophyllum*, often misapplied in cultivation)	Santa maria (names "mast wood," "Alexandrian laurel" used in cultivation)	I		1
Casuarina equisetifolia	Australian pine	I	P	1
Casuarina glauca	Suckering Australian pine	I	P	1
Cestrum diurnum	Day jessamine	I		1
Cinnamomum camphora	Camphor-tree	I		1
Colocasia esculenta	Wild taro	I		1
Colubrina asiatica	Lather leaf	I		1
Cupaniopsis anacardioides	Carrotwood	I	N	1
Dioscorea alata	Winged yam	I	N	1
Dioscorea bulbifera	Air-potato	I	N	1
Eichhornia crassipes	Water-hyacinth	I	P	1
Eugenia uniflora	Surinam cherry	I		1
Ficus microcarpa (*F. nitida* and *F. retusa* var. *nitida* misapplied)	Laurel fig	I		1
Hydrilla verticillata	Hydrilla	I	P, N	1
Hygrophila polysperma	Green hygro	I	P, N	1
Hymenachne amplexicaulis	West Indian marsh grass	I		1
Imperata cylindrica (*Imperata brasiliensis* misapplied)	Cogon grass	I	N	1
Ipomoea aquatica	Waterspinach	I	P, N	1
Jasminum dichotomum	Gold Coast jasmine	I		1
Jasminum fluminense	Brazilian jasmine	I		1
Lantana camara	Lantana, shrub verbena	I		1
Ligustrum sinense	Chinese privet, hedge privet	I		1
Lonicera japonica	Japanese honeysuckle	I		1

(Sheet 1 of 4)

Table B7 (Continued)

Scientific Name	Common Name	FLEPPC Rank	Government Listed	COC Rank
	Category I (Concluded)			
Lygodium japonicum	Japanese climbing fern	I	N	1
Lygodium microphyllum	Old World climbing fern	I	N	1
Macfadyena unguis-cati	Cat's claw vine	I		1
Melaleuca quinquenervia	Melaleuca, paper bark	I	P, N	1
Melia azedarach	Chinaberry	I		1
Mimosa pigra	Catclaw mimosa	I	P, N	
Nandina domestica	Nandina, heavenly bamboo	I		
Nephrolepis cordifolia	Sword fern	I		
Nephrolepis multiflora	Asian sword fern	I		
Neyraudia reynaudiana	Burma reed; cane grass	I	N	1
Paederia cruddasiana	Sewer vine, onion vine	I	N	1
Paederia foetida	Skunk vine	I	N	1
Panicum repens	Torpedo grass	I		1
Pennisetum purpureum	Napier grass	I		1
Pistia stratiotes	Water lettuce	I	P	1
Psidium cattleianum (=*P. littorale*)	Strawberry guava	I		1
Psidium guajava	Guava	I		1
Pueraria montana (=*P. lobata*)	Kudzu	I	N	1
Rhodomyrtus tomentosa	Downy rose-myrtle	I	N	1
Rhoeo spathacea (=*R. discolor; Tradescantia spathacea*)	Oyster plant	I		1
Sapium sebiferum	Popcorn tree, Chinese tallow tree	I	N	1
Scaevola sericea (=*Scaevola taccada* var. *sericea, S. frutescens*)	Scaevola, half-flower, beach naupaka	I		1
Schefflera actinophylla (=*Brassaia actinophylla*)	Schefflera, Queensland umbrella tree	I		1
Schinus terebinthifolius	Brazilian pepper	I	P, N	1
Senna pendula (=*Cassia coluteoides*)	Climbing cassia, Christmas cassia, Christmas senna	I		1
Solanum tampicense (=*S. houstonii*)	Wetland night shade, aquatic soda apple	I	N	1
Solanum torvum	Susumber, turkey berry	I	N	1
Solanum viarum	Tropical soda apple	I	N	1
Syzygium cumini	Jambolan, Java plum	I		1
Tectaria incisa	Incised halberd fern	I		1
Thespesia populnea	Seaside mahoe	I		1
Tradescantia fluminensis	White-flowered wandering jew	I		1
Urochloa mutica (=*Brachiaria mutica*)	Pará grass	I		1

(Sheet 2 of 4)

Table B7 (Continued)				
Scientific Name	**Common Name**	**FLEPPC Rank**	**Government Listed**	**COC Rank**
Category II – Species that have shown a potential to disrupt native plant communities. These species may become ranked as Category I, but have not yet demonstrated disruption of natural Florida communities.				
Adenanthera pavonina	Red sandalwood	II		1
Agave sisalana	Sisal hemp	II		1
Aleurites fordii	Tung oil tree	II		1
Alstonia macrophylla	Devil-tree	II		1
Alternanthera philoxeroides	*Alligator weed*	II	P	1
Anredera leptostachya	*Madeira vine*	II		1
Antigonon leptopus	Coral vine	II		1
Aristolochia littoralis	Calico flower	II		1
Asystasia gangetica	Ganges primrose	II		1
Begonia cucullata	Begonia	II		1
Broussonetia papyrifera	Paper mulberry	II		1
Callisia fragrans	Inch plant, spironema	II		1
Casuarina cunninghamiana	Australian pine	II	P	1
Cereus undatus (=*Hylocereus undatus*)	Night-blooming cereus	II		1
Clerodendrum bungei	Strong-scented glorybower	II		1
Cryptostegia madagascariensis	*Rubber vine*	II		1
Cyperus alternifolius (=*C. involucratus*)	Umbrella plant	II		1
Cyperus prolifer	Dwarf papyrus	II		1
Dalbergia sissoo	Indian rosewood, sissoo	II		1
Eleagnus pungens	Thorny eleagnus	II		1
Enterolobium contortisilquum	Ear-pod tree	II		1
Epipremnum pinnatum cv. Aureum	Pothos	II		1
Ficus altissima	False banyan	II		1
Flacourtia indica	Governor's plum	II		1
Flueggea virosa	Chinese waterberry	II		1
Hibiscus tiliaceus	Mahoe, sea hibiscus	II		1
Hiptage benghalensis	Hiptage	II		1
Jasminum sambac	Arabian jasmine	II		1
Koelreuteria elegans	Golden rain tree	II		1
Leucaena leucocephala	Lead tree	II		1
Ligustrum lucidum	Glossy privet	II		1
Livistona chinensis	Chinese fan palm	II		1
				(Sheet 3 of 4)

Table B7 (Concluded)

Scientific Name	Common Name	FLEPPC Rank	Government Listed	COC Rank
Category II (Concluded)				
Melinis minutiflora	Molasses grass	II		1
Merremia tuberosa	Wood-rose	II		1
Murraya paniculata	Orange-jessamine	II		1
Myriophyllum spicatum	Eurasian water-milfoil	II	P	1
Ochrosia parviflora (=*O. elliptica*)	Kopsia	II		1
Oeceoclades maculata	Ground orchid	II		1
Passiflora biflora	Twin-flowered passion vine	II		1
Passiflora foetida	Stinking passion-flower	II		1
Phoenix reclinata	Senegal date palm	II		1
Phyllostachys aurea	Golden bamboo	II		1
Pteris vittata	Chinese brake	II		1
Ptychosperma elegans	Solitary palm	II		1
Rhynchelytrum repens	Natal grass	II		1
Ricinus communis	Castor bean	II		1
Ruellia brittoniana (=*R. tweediana*)	Mexican petunia	II		1
Sansevieria hyacinthoides (=*S. trifasciata*)	Bowstring hemp	II		1
Sesbania punicea	Purple sesban, rattlebox	II		1
Solanum diphyllum	Twinleaf nightshade	II		1
Solanum jamaicense	Jamiaca nightshade	II		1
Syngonium podophyllum	Arrowhead vine	II		1
Syzygium jambos	Rose-apple	II		1
Terminalia catappa	Tropical almond	II		1
Tribulus cistoides	Puncture vine, burnut	II		1
Triphasia trifoliata	Lime berry	II		1
Urena lobata	Caesar's weed	II		1
Wedelia trilobata	Wedelia	II		1
Wisteria sinensis	Chinese wisteria	II		1
Xanthosoma sagittifolium	Melanga, elaphant ear	II		1

(Sheet 4 of 4)

Overstory Data

SITE INFORMATION - DESCRIPTION			
GATHERED BY:	Joe Field Guy	Enter # of 0.04-ha subplots (up to 3)	3
SITE NAME:	River A	DATE:	1/12/00
DISTURBANCE:	Reference Standard	Multiplication Factor	8.3835

Item #	Spp #	dbh	Species	COC	g
1	2	25	*Carpinus caroliniana*	5	0.049088
2	2	20	*Carpinus caroliniana*	5	0.031416
3	2	28	*Carpinus caroliniana*	5	0.061575
4	2	22	*Carpinus caroliniana*	5	0.038013
5	16	32	*Nyssa biflora*	5	0.080425
6	16	31	*Nyssa biflora*	5	0.075477
7	16	36	*Nyssa biflora*	5	0.101788
8	23	28	*Tilia americana*	5	0.061575
9	23	25	*Tilia americana*	5	0.049088
10	5	35	*Celtis laevigata*	4	0.096212
11	5	25	*Celtis laevigata*	4	0.049088
12	6	12	*Citrus sp.*	2	0.01131
13	6	13	*Citrus sp.*	2	0.013273
14	22	22	*Taxodium distichum*	5	0.038013
15	22	42	*Taxodium distichum*	5	0.138545
16	1	22	*Acer rubrum*	4	0.038013
17	19	30	*Quercus lauriflora*	5	0.070686
18	19	44	*Quercus lauriflora*	5	0.152053
19	19	46	*Quercus lauriflora*	5	0.166191
20	24	42	*Ulmus americana*	5	0.138545
21	24	45	*Ulmus americana*	5	0.159044
22					
23					
24					

		Density/ha		Basal Area/ha		Diversity
		528.17		40.73		9
COC	COC and Relative % Based on dbh					
ID	1	2	3	4	5	
g	0	0.62	0	4.61	35.50	
Relative %	0	1.52	0	11.32	87.16	**COC Value**
Factor	0	0.3	0.5	0.8*	1	**96.67**

Calculated COC Example (Overstory Data)

Understory Data Sheet

SITE INFORMATION - DESCRIPTION			
GATHERED BY:	Joe Field Guy	Enter # of 0.004-ha subplots (up to 6)	1
SITE NAME:	River A	DATE:	1/12/00
DISTURBANCE:	Reference Standard	Multiplication Factor	100

Item #	SPP #	# of STEMS	Species	COC
1	2	3	*Bumelia reclinata*	5
2	1	3	*Acer rubrum*	4
3	3	2	*Carpinus caroliniana*	5
4	5	1	*Acer rubrum*	4
5	8	4	*Citrus sp.*	2
6	4	3	*Carya aquatica*	5
7	6	5	*Celtis laevigata*	4
8	7	4	*Cephalanthus occidentalis*	5
9			#N/A	#N/A
10			#N/A	#N/A
11			#N/A	#N/A
12			#N/A	#N/A
13			#N/A	#N/A
14			#N/A	#N/A
15			#N/A	#N/A

	Actual Density		Density m^2/ha		Diversity
	25		2500		7
COC	COC and Relative %				
ID	1	2	3	4	5
	0	400	0	900	1200
Relative %	0	16	0	36	48
Factor	0	0.3	0.5	0.8 *	1

COC Value
81.60

COC Overstory **96.67**
COC Understory **81.60**
FQI **<u>178.27</u>** **A subindex of 0.7 is assigned for this site.**

*Use multiplicative factor of 0.8 if the percentage is < 40%
Use multiplicative factor of 0.1 if the percentage is > 40%

Calculated COC Example (Understory Data)

22. Dominant Ground Cover Species Composition (V_{DGCS})

Measure/Units: Species diversity measurement of dominant ground cover vegetation.

Methods: (1) Identify the ground cover dominants by summing the relative cover, as a measure of abundance, beginning with the most abundant species in descending order until 50 percent is exceeded. Additional species with ≥10 percent relative abundance should also be considered as dominants.

(2) Calculate percent concurrence by comparing the list of dominant ground cover species to the list of dominant species found in reference standard wetlands (Table B6). For example, if all the dominants from the area being assessed occur on the list of dominants from reference standard wetlands, then there is 100 percent concurrence. If three out of the five dominant ground cover species from the area being assessed occur on the list, then there is 60 percent concurrence. Exotic ground cover dominance does not receive a value. For example, if three out of six dominant ground cover species from the area being assessed occur on the list, and an additional dominant species is an exotic, then there is 50 percent concurrence:

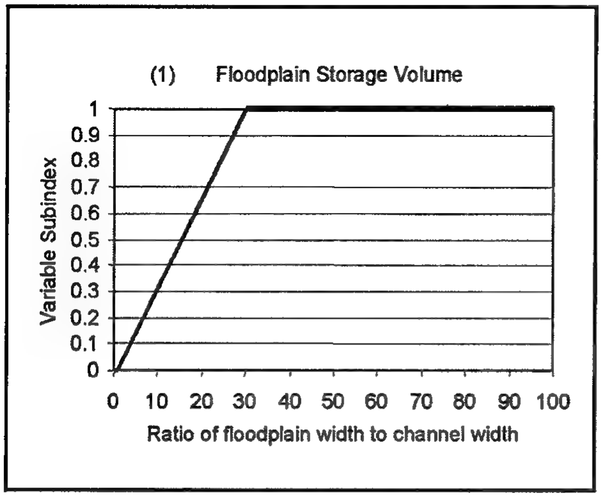
$$3 + 0 = 3/6 = 50 \text{ percent} \qquad \text{(B19)}$$

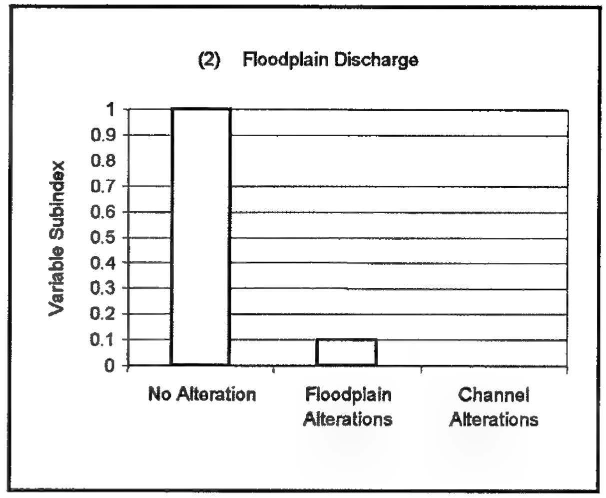
(3) Report concurrence of ground cover species dominants as a percent.

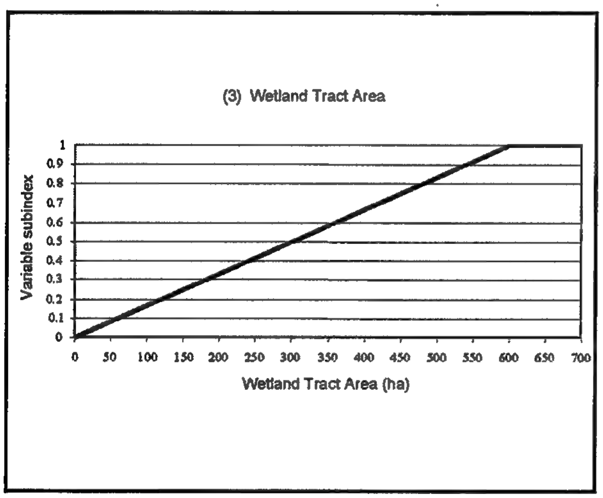
Summary of Variables by Function

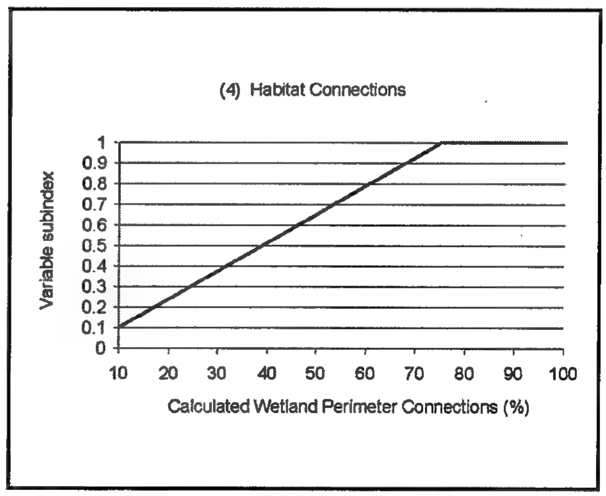
Variables		Function
1. Wetland Tract Area	V_{AREA}	Provide Wildlife Habitat
2. Habitat Connections	$V_{CONNECT}$	Provide Wildlife Habitat
3. Floodplain Discharge	V_{FDC}	Temporary Storage of Surface Water Retention of Particulates
4. Floodplain Storage Volume	V_{STORE}	Temporary Storage of Surface Water
5. Overbank Flood Frequency	V_{FREQ}	Temporary Storage of Surface Water Removal and Sequestration of Elements Retention of Particulates Organic Carbon Export Provide Environment for Native Plant Community Provide Wildlife Habitat
6. Floodplain Roughness	V_{ROUGH}	Temporary Storage of Surface Water
7. Water Table Slope	$V_{WTSLOPE}$	Storage and Conveyance of Groundwater
8. Surface Water Connections	$V_{SURFCON}$	Organic Carbon Export
9. Extent of Ponding	V_{POND}	Provide Environment for Native Plant Community Provide Wildlife Habitat
10. Soil Integrity	$V_{SOILINT}$	Provide Environment for Native Plant Community
11. Hydric Soil Indicators	V_{HSOIL}	Removal and Sequestration of Elements
12. Water Table Depth	V_{WTD}	Provide Environment for Native Plant Community
	V_{HSOIL}	Removal and Sequestration of Elements
13. Soil Clay Content	V_{CLAY}	Removal and Sequestration of Elements
14. Saturated Hydraulic Conductivity	$V_{CONDUCT}$	Storage and Conveyance of Groundwater
15. Tree Biomass	V_{TDBH}	Cycling of Nutrients Provide Environment for Native Plant Community Provide Wildlife Habitat
16. Woody Debris Biomass	V_{WDB}	Organic Carbon Export Provide Wildlife Habitat
17. Understory Vegetation Biomass	V_{UVB}	Cycling of Nutrients Provide Environment for Native Plant Community Provide Wildlife Habitat
18. Ground Vegetation Biomass	V_{GVB}	Cycling of Nutrients
19. Soil O Horizon	V_{OHOR}	Cycling of Nutrients Removal and Sequestration of Elements Organic Carbon Export Provide Wildlife Habitat
20. Soil A Horizon	V_{AHOR}	Cycling of Nutrients Removal and Sequestration of Elements
21. Overstory and Understory Species Composition	V_{OUS}	Provide Environment for Native Plant Community Provide Wildlife Habitat
22. Dominant Ground Cover Species Composition	V_{DGCS}	Provide Environment for Native Plant Community

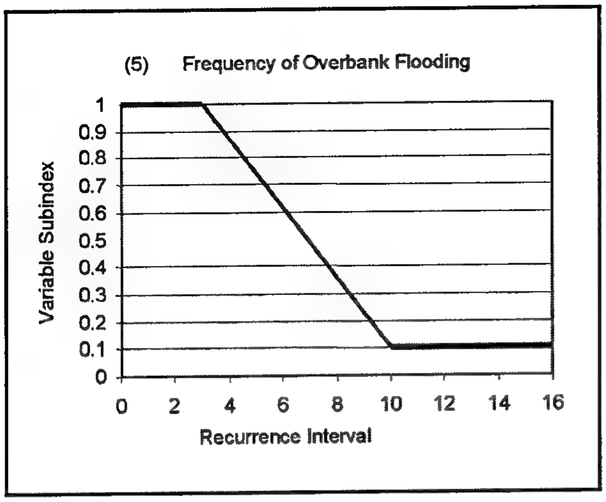
Summary of Graphs for Transforming Measures to Subindices

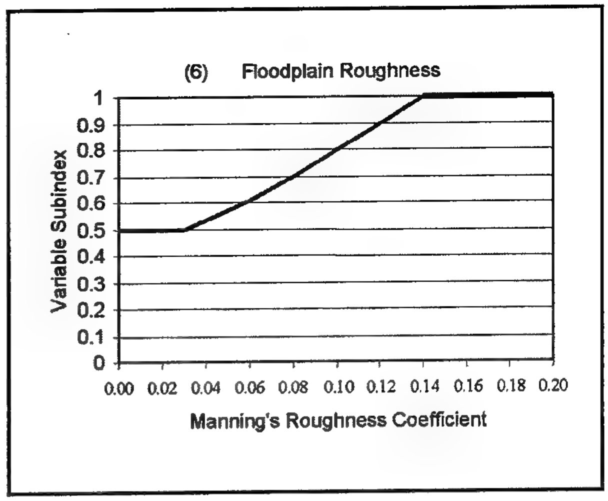


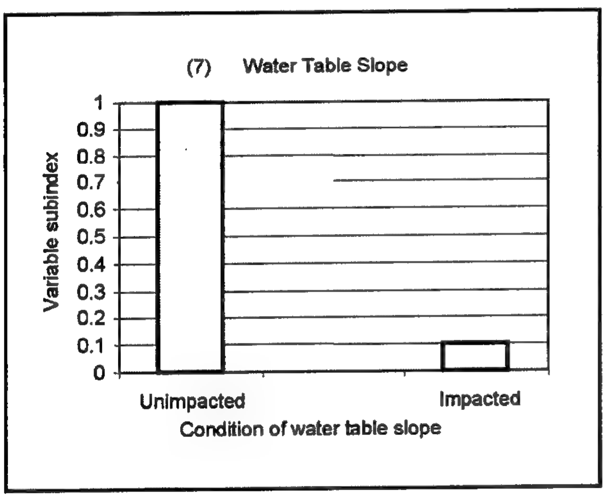


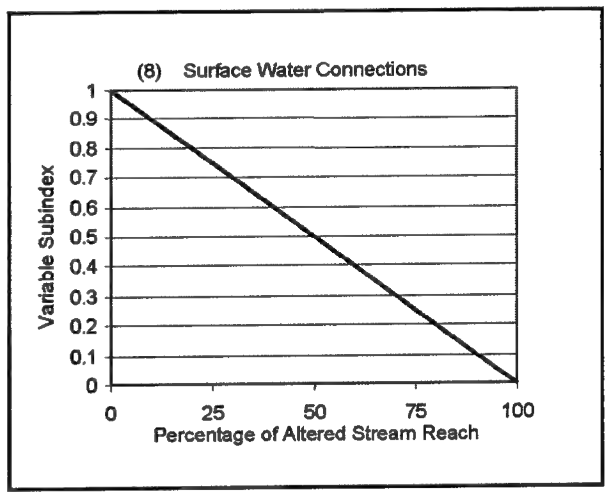


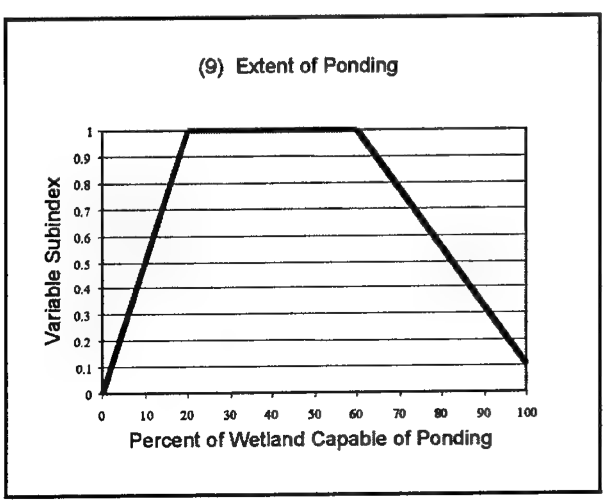


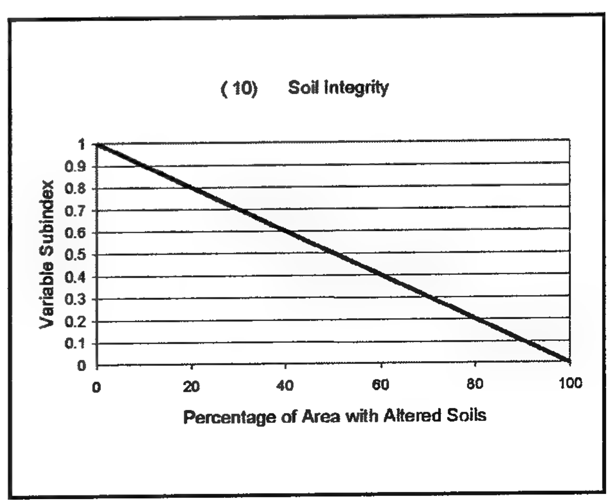

(5) Frequency of Overbank Flooding
Variable Subindex
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 2 4 6 8 10 12 14 16
Recurrence Interval

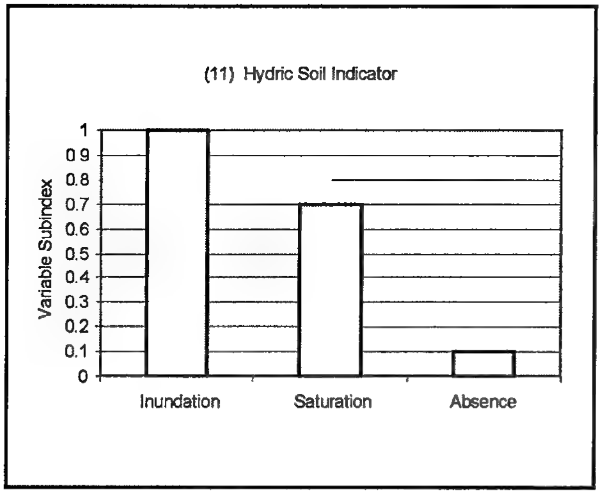

(6) Floodplain Roughness
Variable Subindex
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0.00 0.02 0.04 0.06 0.08 0.10 0.12 0.14 0.16 0.18 0.20
Manning's Roughness Coefficient

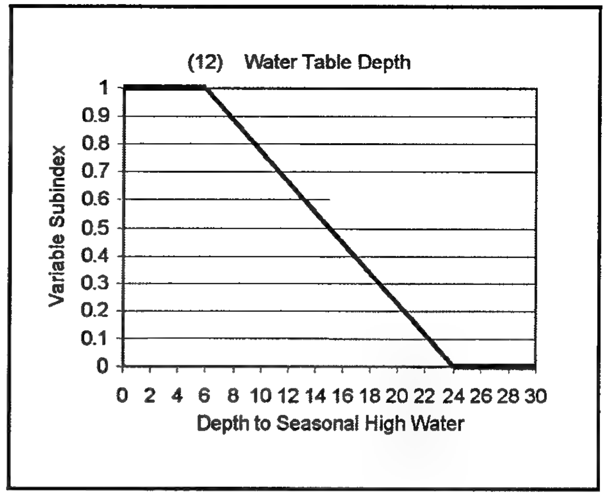

(7) Water Table Slope
Variable subindex
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Unimpacted
Impacted
Condition of water table slope

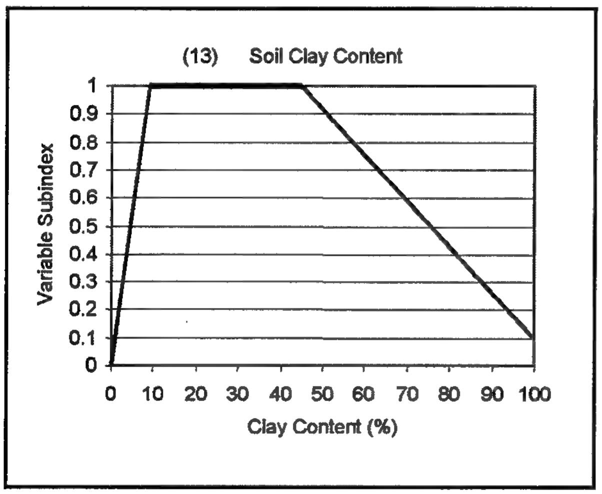

(8) Surface Water Connections
Variable Subindex
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 25 50 75 100
Percentage of Altered Stream Reach

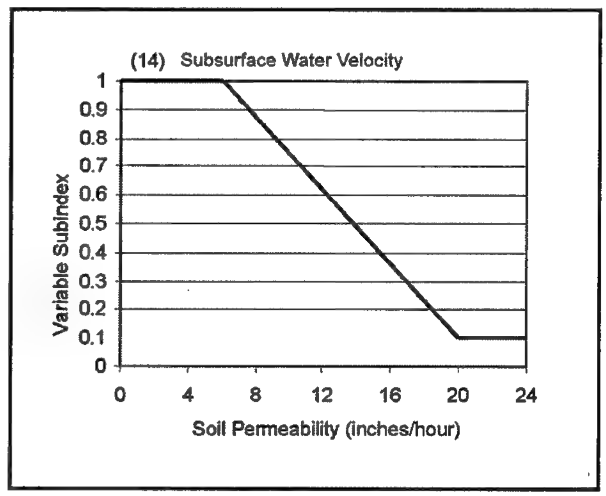

(9) Extent of Ponding
Variable Subindex
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 10 20 30 40 50 60 70 80 90 100
Percent of Wetland Capable of Ponding

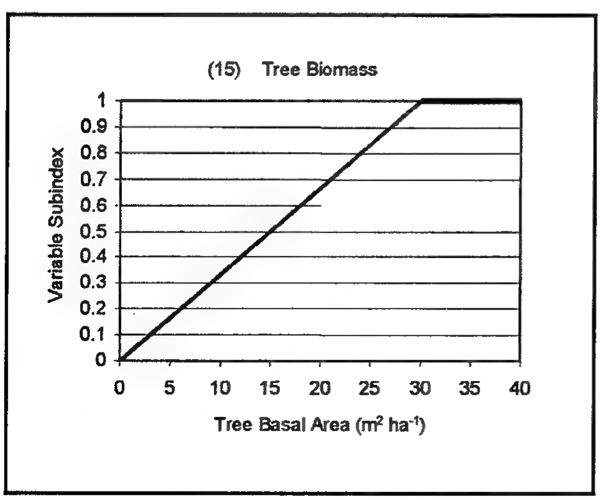

(10) Soil Integrity
Variable Subindex
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 20 40 60 80 100
Percentage of Area with Altered Soils

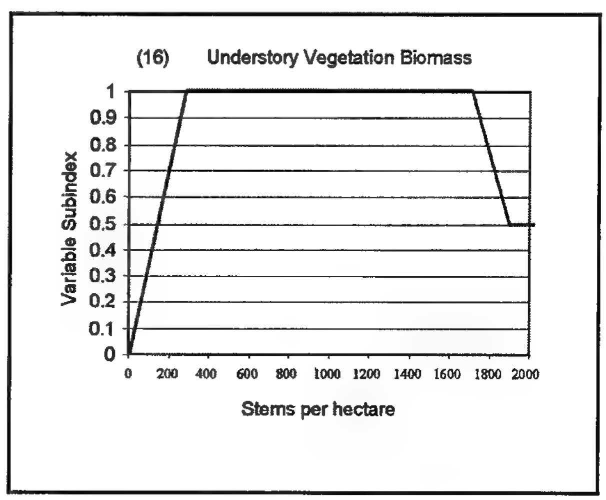

(11) Hydric Soil Indicator
Variable Subindex
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Inundation
Saturation
Absence

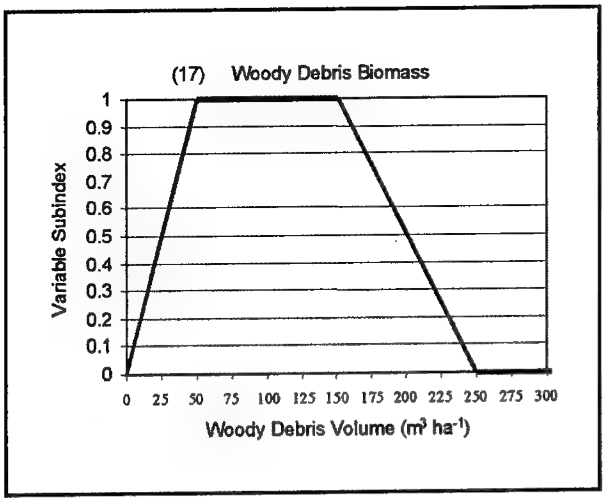

(12) Water Table Depth
Variable Subindex
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
Depth to Seasonal High Water

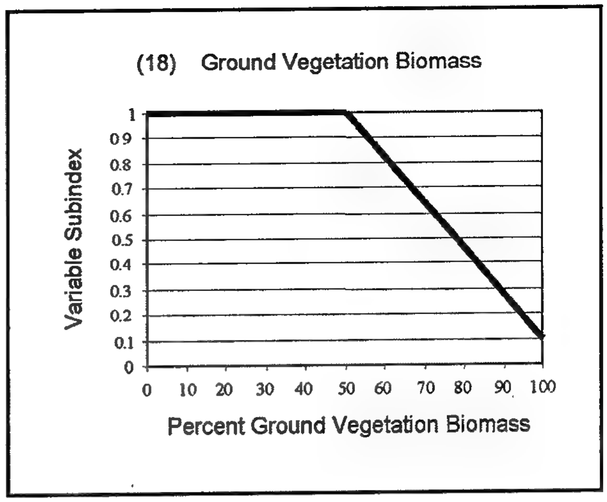

(13) Soil Clay Content
Variable Subindex
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 10 20 30 40 50 60 70 80 90 100
Clay Content (%)

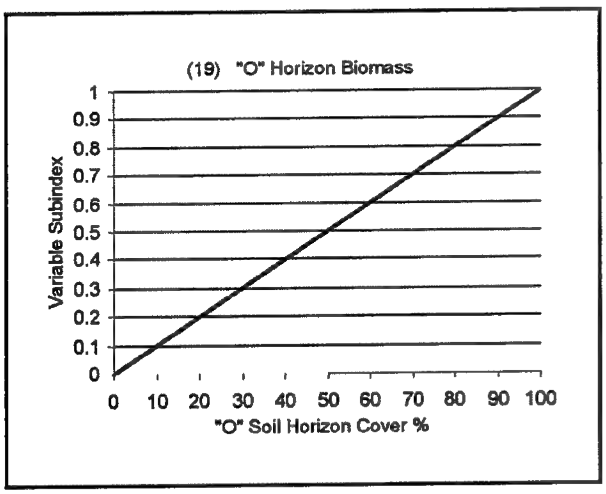

(14) Subsurface Water Velocity
Variable Subindex
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 4 8 12 16 20 24
Soil Permeability (inches/hour)

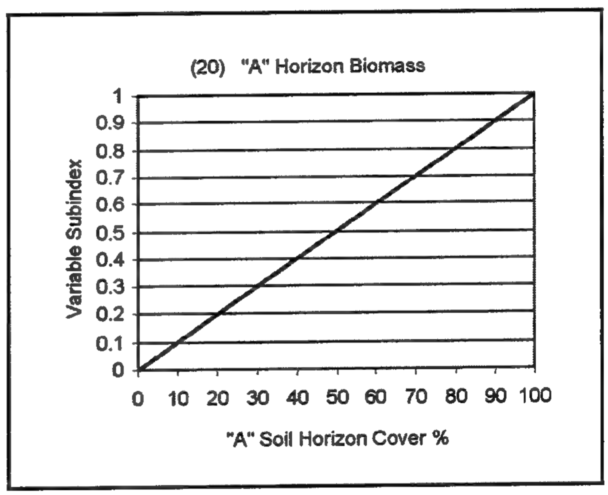

(15) Tree Biomass
Variable Subindex
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 5 10 15 20 25 30 35 40
Tree Basal Area (m² ha⁻¹)

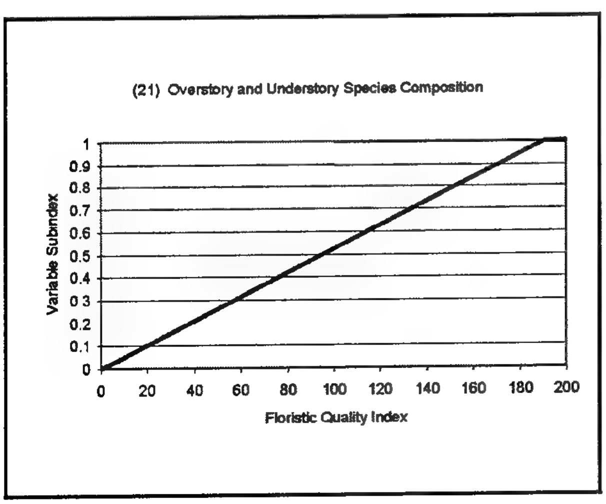

(16) Understory Vegetation Biomass
Variable Subindex
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 200 400 600 800 1000 1200 1400 1600 1800 2000
Stems per hectare

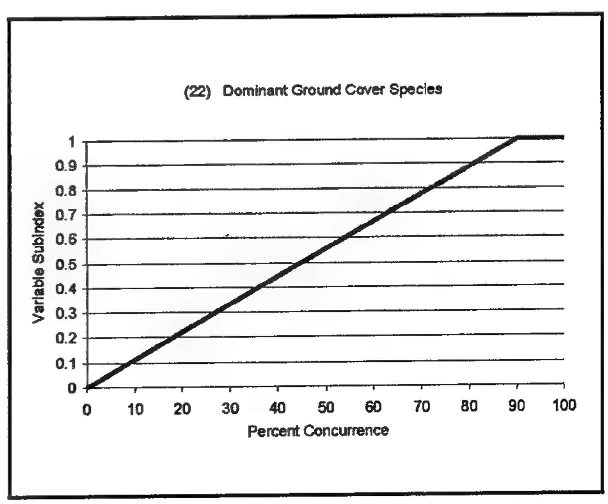

(17) Woody Debris Biomass
Variable Subindex
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 25 50 75 100 125 150 175 200 225 250 275 300
Woody Debris Volume (m³ ha⁻¹)


(18) Ground Vegetation Biomass
Variable Subindex
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 10 20 30 40 50 60 70 80 90 100
Percent Ground Vegetation Biomass


(19) "O" Horizon Biomass
Variable Subindex
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 10 20 30 40 50 60 70 80 90 100
"O" Soil Horizon Cover %


(20) "A" Horizon Biomass
Variable Subindex
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 10 20 30 40 50 60 70 80 90 100
"A" Soil Horizon Cover %


(21) Overstory and Understory Species Composition
Variable Subindex
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 20 40 60 80 100 120 140 160 180 200
Floristic Quality Index


(22) Dominant Ground Cover Species
Variable Subindex
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0 10 20 30 40 50 60 70 80 90 100
Percent Concurrence

Blank Field Data Sheet

Field Data Sheet
Low Gradient Riverine Wetlands in West Central Peninsular Florida

Assessment Team: ____

Project Name/Location: ____________________________________ Date:__________

Sample variables 1-4 using aerial photos, topographic maps, scenic overlooks, local informants, tables, surveys, etc.

1. V_{TRACT} Area of wetland that is contiguous with the WAA *and* of the same subclass _____ha

2. $V_{CONNECT}$ Percent of wetland tract perimeter that is "connected" to suitable habitat ....._____%

3. V_{SLOPE} Percent floodplain slope..._____%

4. V_{STORE} Floodplain width to channel width ratio..._____

Sample variables 5-14 based on a walking reconnaissance of the WAA.

5. V_{FREQ} Overbank flood recurrence interval.._____yrs
Check data source: gage data__, local knowledge__, flood frequency curves__, Regional dimensionless curve__, hydrologic modeling__, other___________.

6. V_{ROUGH} Roughness Coefficient:
0.026 (n_{BASE}) + ___ (n_{TOPO}) + ___ (n_{OBS}) + ___ (n_{VEG}) =........................._____

7. $V_{WTSLOPE}$ Percent of WAA with an altered water table slope................................_____%

8. $V_{SURFCON}$ Percent of adjacent stream reach with altered surface connections.............._____%

9. V_{POND} Percent of WAA that is capable of ponding water for extended periods........._____%

10. $V_{SOILINT}$ Percent of WAA with altered soils.._____%

11. V_{HSOIL} Hydric soil indicators (check one) Absence_____Inundation_____Saturation_____

12. V_{WTD} Water table depth is..._____inches
Check data source: groundwater well___, redoximorphic features___, County Soil Survey___.

13. V_{CLAY} Percent of WAA with altered clay content in soil profile...................... _____%

14. $V_{CONDUCT}$ Saturated hydraulic conductivity or Soil Profile Alteration (check one):
No alteration to soils___, Top 6 in altered___, Entire profile altered___.

Sample variable 15 from a representative number of locations in the WAA using a 0.04 ha circular plot (11.3 m (37 ft) radius).

15. V_{TBA} Tree basal area (average of 0.04 ha plot values on next line)..................._____m^2/ha
0.04 ha plots: 1____m^2/ha 2____m^2/ha 3____m^2/ha 4____m^2/ha

Sample variable 16 on two (2) 15 m transects partially within the 0.04 ha plot.

16. V_{WD} Volume of woody debris (average of transect values on next line)..........._____m^3/ha
Transect: 1____m^3/ha 2____m^3/ha 3____m^3/ha 4____m^3/ha

(Sheet 1 of 2)

Sample variable 17 in two (2) 0.004 ha circular subplots (3.6 m (11.8 ft) radius) placed in representative locations of the 0.04 ha plot.

17. V_{SSD} Number of woody understory stems (average of 0.04 ha plot values on next line) ...._____stems/ha

0.04 ha plots: 1_____stems/ha 2_____stems/ha 3_____stems/ha 4____stems/ha

Sample variables 18-22 in four (4) m^2 subplots placed in representative locations of each quadrant of the 0.04 ha plot.

18. V_{GVC} Average cover of ground vegetation (average of 0.04 ha plot values on next line) ...._____%

Average of 0.04 ha plots sampled: 1____% 2____% 3____% 4____%

19. V_{OHOR} Average cover of "O" Horizon (average of 0.04 ha plot values on next line)_____%

Average of 0.04 ha plots sampled: 1____% 2____% 3____% 4____%

20. V_{AHOR} Average cover of "A" Horizon (average of 0.04 ha plot values on next line)_____%

Average of 0.04 ha plots sampled: 1____% 2____% 3____% 4____%

21. V_{OUS} Calculate the Floristic Quality Index of all trees and shrubs....................._____%

22. V_{DGCS} Concurrence with ground cover vegetation dominants (average of 0.04ha plot values on next line).._____%

Average of 0.04 ha plots sampled: 1____% 2____% 3____% 4____%

(Sheet 2 of 2)

Blank Plot Worksheet

Plot Worksheet: Low Gradient Riverine Wetlands in West Central Florida

Assessment Team:______________________

Project Name:_________________________ Plot Number:__________

Date:__________

13. V_{CLAY} Field Texture determination of clay content in soils.

Plot 1

Depth ______ Texture class clay % ______ = Depth X % Clay ________

Depth ______ Texture class clay % ______ = Depth X % Clay ________

Depth ______ Texture class clay% ______ = Depth X % Clay ________

Depth ______ Texture class clay% ______ = Depth X % Clay ________

Depth ______ Texture class clay% ______ = Depth X % Clay ________

Total Depth 20 inches = Total ________

Percent Clay = Total / Total Depth (20 inches) _______% Clay

Plot 2

Depth ______ Texture class clay % ______ = Depth X % Clay ________

Depth ______ Texture class clay % ______ = Depth X % Clay ________

Depth ____ Texture class clay %______ = Depth X % Clay ________

Depth ______ Texture class clay% ______ = Depth X % Clay ________

Depth ______ Texture class clay% ______ = Depth X % Clay ________

Total Depth 20 inches = Total ________

Percent Clay = Total / Total Depth (20 inches) _______% Clay

Plot 3

Depth ______ Texture class clay % ______ = Depth X % Clay ________

Depth ______ Texture class clay % ______ = Depth X % Clay ________

Depth ______ Texture class clay% ______ = Depth X % Clay ________

Depth ______ Texture class clay% ______ = Depth X % Clay ________

Depth ______ Texture class clay% ______ = Depth X % Clay ________

Total Depth 20 inches = Total ________

Percent Clay = Total / Total Depth (20 inches) _______% Clay

Determine Weighted Average of Percent Clay (WAPC): Multiply % Wetland Area X % Clay

Percentage of Wetland area having ______ % Clay = ______X______ = _____

Percentage of Wetland area having ______ % Clay = ______X ______= _____

Percentage of Wetland area having ______ % Clay = ______X ______= _____

Percentage of Wetland area having ______ % Clay = ______X ______= _____

Percentage of Wetland area having ______ % Clay = ______X ______= _____

Percentage of Wetland area having ______ % Clay = ______X ______= _____

Total _____ X 100% = WAPC

(Sheet 1 of 5)

Plot Worksheet: Low Gradient Riverine Wetlands in West Central Florida

Assessment Team:__________________________
Project Name:______________________________ Plot Number:__________
Date:__________

15. V_{TBA} Tree Basal Area. Record dbh (cm) of trees by species below, square dbh values (cm^2), multiply result by 0.000079 (m^2), and sum resulting values in shaded columns (m^2/0.04 ha). Record in space provided below worksheet , multiply by 25 (m^2/ha).

Species	dbh (cm)	dbh^2 (cm^2)	× 0.000079 (m^2/0.04 ha)	Species	dbh (cm)	dbh^2 (cm^2)	× 0.000079 (m^2/0.04 ha)

Sum of values from shaded columns above =_____ (m^2/0.04 ha) x 25 = ______ m^2/ha.

(Sheet 2 of 5)

Plot Worksheet: Low Gradient Riverine Wetlands in West Central Florida

Assessment Team:________________________
Project Name:____________________________ Plot Number:__________
Date:_________

16. V_{WD} Woody Debris Biomass

A. Record number of stems in size class 1 (0.6–2.5 cm / 0.25–1 in) along 2 - 50 ft (15 m) Transects for plots; Plot 1. Transect 1 _____ Transect 2_____ Total number of stems = _______

Plot 2. Transect 1 _____ Transect 2_____ Total number of stems = _______
Plot 3. Transect 1 _____ Transect 2_____ Total number of stems = _______

Size Class 1 tons/acre = 0.187 × total number of stems from 3 plots = ..._____tons/acre

B. Record number of stems in size class 2 (2.5–7.6cm / 1–3 in) along 2 - 50 ft (15 m) Transects for all plots; Plot 1. Transect 1 _____ Transect 2 _____Total number of stems = _______

Plot 2. Transect 1 _____ Transect 2 _____Total number of stems = _______
Plot 3. Transect 1 _____ Transect 2 _____Total number of stems = _______

Size Class 2 tons/acre = 0.892 × total number of stems =................... _______ tons/acre

C. Record diameter of stems in size class 3 (>7.6 cm / >3 in) along 2 - 50 ft (15 m)Transects for all plots;

Plot 1: Transect 1	diameter	diameter^2	Transect 2	diameter	diameter^2
Stem 1 =	_____	_____	Stem 1 =	_____	_____
Stem 2 =	_____	_____	Stem 2 =	_____	_____
Stem 3 =	_____	_____	Stem 3 =	_____	_____
Stem 4 =	_____	_____	Stem 4 =	_____	_____
Stem 5 =	_____	_____	Stem 5 =	_____	_____
Stem 6 =	_____	_____	Stem 6 =	_____	_____
Stem 7 =	_____	_____	Stem 7 =	_____	_____
Stem 8 =	_____	_____	Stem 8 =	_____	_____
Total diameter^2		_____	Total diameter^2		_____

Plot 2: Transect 1	diameter	diameter^2	Transect 2	diameter	diameter^2
Stem 1 =	_____	_____	Stem 1 =	_____	_____
Stem 2 =	_____	_____	Stem 2 =	_____	_____
Stem 3 =	_____	_____	Stem 3 =	_____	_____
Stem 4 =	_____	_____	Stem 4 =	_____	_____
Stem 5 =	_____	_____	Stem 5 =	_____	_____
Stem 6 =	_____	_____	Stem 6 =	_____	_____
Stem 7 =	_____	_____	Stem 7 =	_____	_____
Stem 8 =	_____	_____	Stem 8 =	_____	_____

(Sheet 3 of 5)

Plot Worksheet: Low Gradient Riverine Wetlands in West Central Florida

Assessment Team:____________________ Plot Number:__________
Project Name:____________________
Date:__________

16. V_{WD} (continued)

Total diameter^2 ________ Total diameter^2 ________

Plot 3: Transect 1	diameter	diameter^2	Transect 2	diameter	diameter^2
Stem 1 =			Stem 1 =		
Stem 2 =			Stem 2 =		
Stem 3 =			Stem 3 =		
Stem 4 =			Stem 4 =		
Stem 5 =			Stem 5 =		
Stem 6 =			Stem 6 =		
Stem 7 =			Stem 7 =		
Stem 8 =			Stem 8 =		
Total diameter^2			Total diameter^2		

Size Class 3 tons/acre = 0.0687 × Total diameter^2 of stems from both transects =______ tons/acre

Total tons/acre (sum of size classes 1–3 above) =................................ _______ tons/acre

Cubic feet/acre = (32.05 × total tons/acre) / 0.058 = ... _______ cubic feet/acre

Cubic meters/ha = cubic feet/acre × 0.069 .... _______ cubic meters/ha

17. V_{SSD} Identify and tally woody understory stems from two 0.004 ha subplots in up to 3 plots, then average and multiply by 250:

Species	Tally	Species	Tally

(Sheet 4 of 5)

17. V_{SSD} (continued)

Species	Tally	Species	Tally

Plot 1: Subplot 1_____ Subplot 2_____......................................_____stems/ha
Plot 2: Subplot 1_____ Subplot 2_____......................................_____stems/ha
Plot 3: Subplot 1_____ Subplot 2_____......................................_____stems/ha

Average_____ x 250 = stems/ha

(Sheet 5 of 5)

Appendix C
Supplementary Information on Model Variables

This appendix contains the following summaries:

Soil Texture by Feel

Clay content in soils can be measured in a laboratory by conducting a particle size analysis. However, this is often impracticable in a rapid assessment scenario. Clay content can be estimated in the field using the soil texture by feel to determine the clay content (Figure C1), and the soil texture triangle to estimate percent clay (Figure C2).

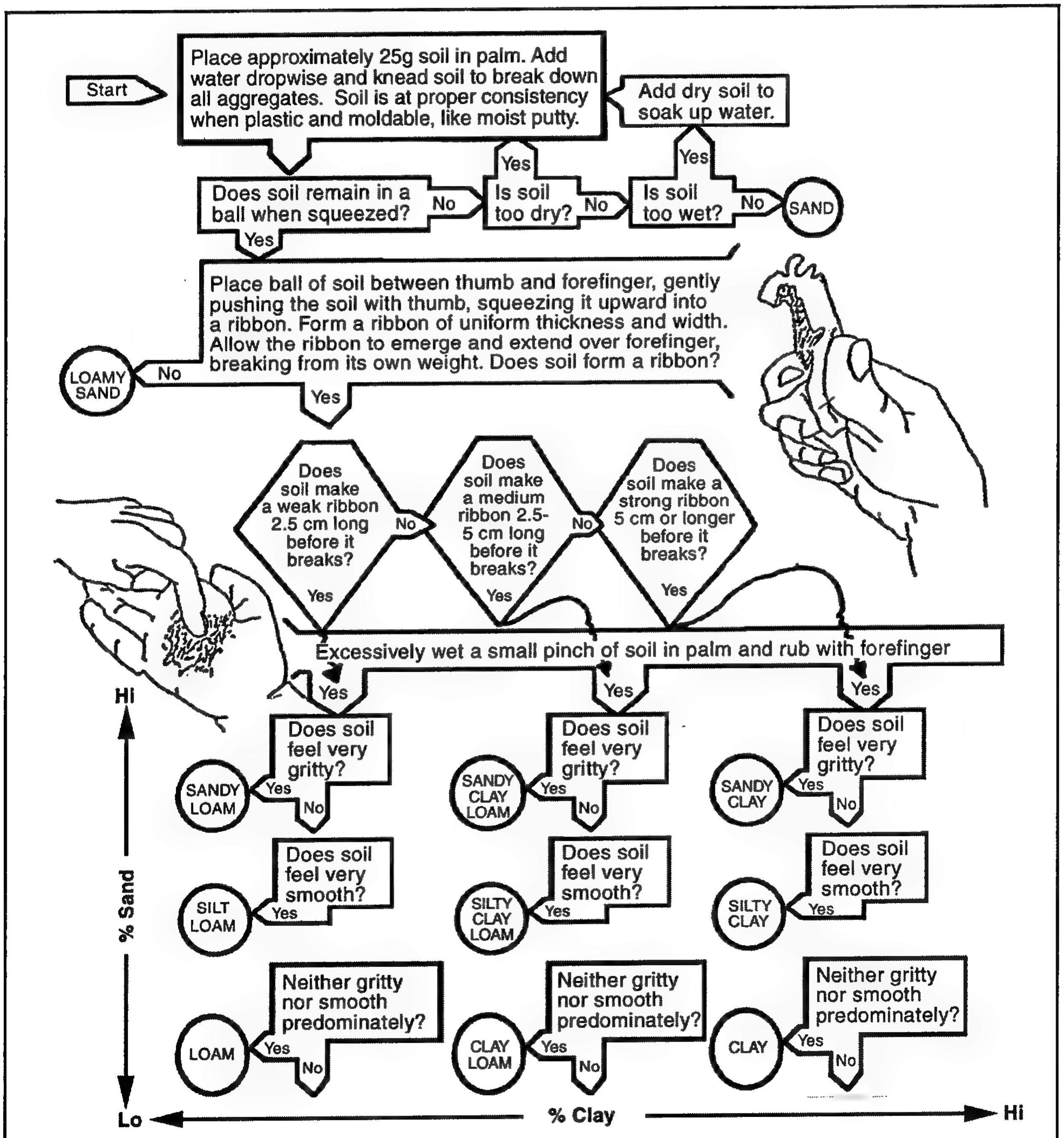


Figure C1. Estimating soil texture by "feel" (adapted from Carlisle and Watts 2000)

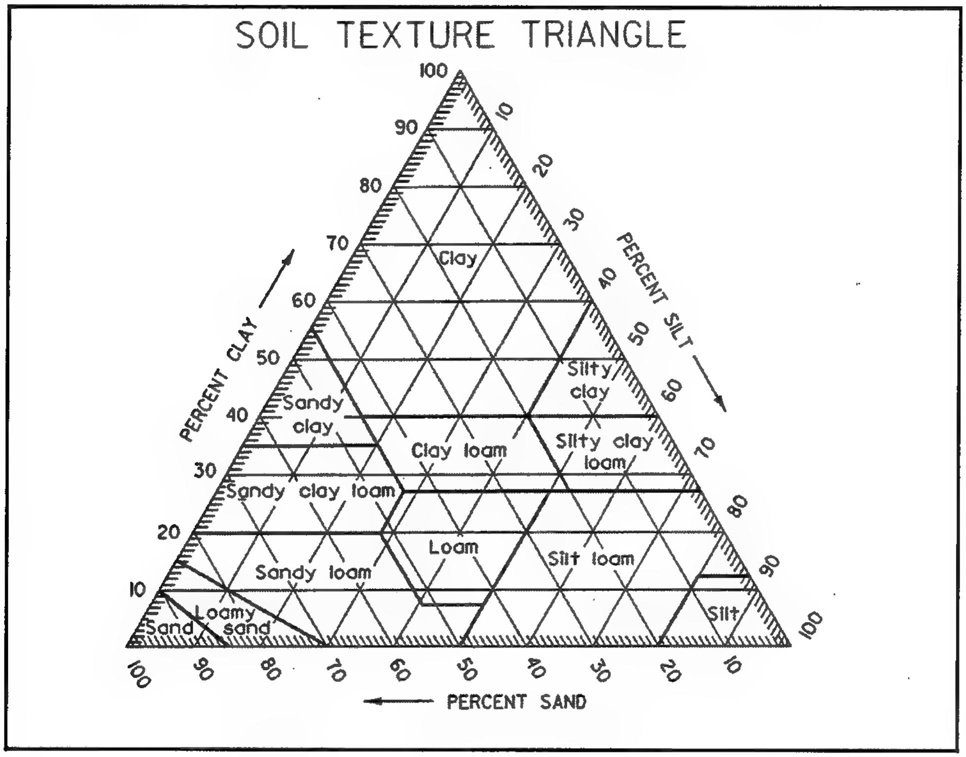


Figure C2. Soil texture triangle

Overbank Flooding Methodology and Calculations (*VFREQ*)

This methodology is broken into three parts for calculation. Part 1 calculates the flood frequency, Part 2 calculates the flood necessary to create overbank flow at the cross-section of interest, and Part 3 relates the flood frequency with the overbank flow to give a recurrence interval of overbank flow.

Part 1

Calculate the flood frequency recurrence intervals Q_T at the site in question. This can be done using one of the following methods:

(1) Flood Frequency Analysis: Regional flood frequency calculations and regression equations developed by U.S. Geological Survey (USGS), Department of Transportation, or U.S. Army Corps of Engineers (Bridges 1982; DelCharco and Hammett in preparation).

(2) Numerical Modeling: Hydrologic models such as HEC-2 (U.S. Army Corps of Engineers 1981, 1982), HEC-RAS (U.S. Army Corps of Engineers 1997), HSPF (Bicknell et al. 1993), Quick-2 (Federal Emergency Management Agency 1995).

(3) Local knowledge.

Method 1 – Flood Frequency Analysis. This is the most common and easiest way to accurately calculate flood frequency recurrence intervals at sites with and without streamflow data. For sites with data, calculations following federal guidelines (USGS 1982) can be made. The general approach to calculating flood frequency for a site with annual peak discharge data is to fit the data to a Log-Pearson Type III distribution and, using the statistical measures of the mean, standard deviation, and skewness of the data, and a generalized, regional skew value, calculate the annual exceedance probability for the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year flood events.

Typically, the calculation of flood frequency values is unnecessary because the USGS and other Federal and state agencies have done these calculations and provide the public with these data and, more importantly, with the regression equations for a given geographical area. Regression equations are provided for the State of Florida in Bridges (1982) and specifically for southwest Florida by DelCharco and Hammett (in preparation). Florida was divided into three regions and regression equations were developed for each. Detailed information exists in these publications on how to calculate the flood frequency of a site if an existing USGS gage is present in the watershed. This can be done using a ratio method, but is restricted to cases when the drainage area ratios at the ungaged site are more than half, but less than twice the drainage area of the gaged site (Bridges

1982). It is not necessary to use the ratio method if a gage exists in the same watershed. The user is referred to Bridges (1982) for the methodology.

To simplify flood frequency calculations using the regression equations, some general assumptions about slope and lake area in percent, and two of the regression equation variables were made to create tables of flood frequency values. Tables C1-C3 present the flood frequency flows for the 2-, 10-, and 25-year recurrence events. These tables may be used in place of the regression equations. They incorporate average values of slope of 0.0056 ft/ft (from 13 reference sites) and 2 percent for lake area. The only input needed to calculate the flood frequency flows for the 2-, 10-, and 25-year recurrence events is drainage area of the stream near the wetland.

Tables C1-C3 apply to three regions defined by Bridges (1982) and are shown in Figure C3.

For this step, and for subsequent steps, it is necessary to know the drainage area of the stream at the wetland of interest. Drainage basins, defined as the area that contributes surface runoff to the river or stream at the point of interest, have been defined for the entire state of Florida. Many of these are given in the annual Water Resources Data books published by the USGS. Contact the USGS in Tallahassee or the local water management district for detailed information. However, this information may have to be modified to fit site-specific areas. To modify a drainage basin, first plot the USGS drainage basin on a USGS quadrangle (1:24,000) map. (These basins are available in Geographic Information System (GIS) format, if the user is familiar with ArcView/ArcInfo software.) Then, identify the wetland of interest and draw drainage basin boundaries from the river at the wetland across contour lines at right angles to the existing drainage basin boundary.

Steps to using Method 1:

(1) Determine the drainage area of the river (flooding source) at the wetland of interest discussed in the preceeding paragraph.

(2) Determine the site's region, A, B, or C, from Figure C3.

(3) Use the drainage area calculated in step 1 to determine the flood frequency recurrence flows Q_2, Q_5, Q_{10} and Q_{25} by Tables C1-C3.

Method 2 – Numerical Modeling. The use of numerical models is widespread. Models have been developed to handle a variety of hydrologic conditions and are often used to calculate the volume and depth of overbank flooding. Models, however, require software and hydrologic expertise, and an extensive data set that are outside the scope of a wetland assessment.

Method 3 – Local Knowledge. This potential method is very limited with its largest drawback that it is very difficult to assess the validity of the data. While there are certainly instances where this method may be very useful, it is more often not even an option.

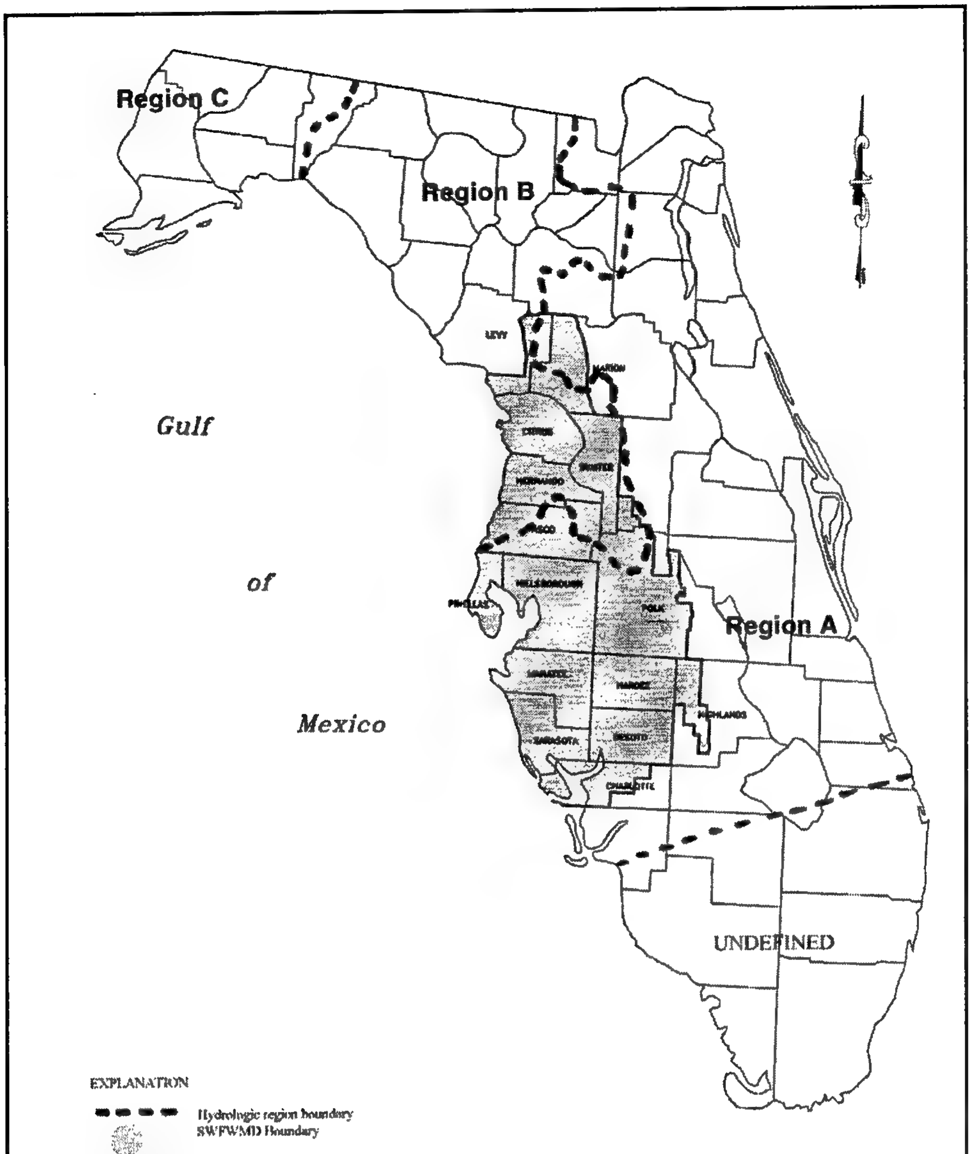


Figure C3. Hydrologic region boundaries of Florida (modified from Bridges 1982)

Table C1
Regression Equations, Region A

Drainage Area, square miles	Q_2, cfs	Q_5, cfs	Q_{10}, cfs	Q_{25}, cfs
10	36	80	118	178
20	62	131	193	289
30	84	176	257	383
40	104	216	315	468
50	123	254	368	546
75	167	341	491	725
100	208	419	602	885
125	246	493	705	1034
150	282	562	802	1174
175	317	628	894	1307
200	351	692	983	1434
225	384	753	1069	1556
250	415	813	1151	1675
275	446	871	1232	1790
300	477	927	1310	1901
325	506	982	1386	2010
350	536	1036	1461	2117
375	564	1089	1534	2221
400	593	1141	1606	2323
425	620	1192	1676	2423
450	648	1242	1746	2521
475	675	1292	1814	2618
500	701	1340	1881	2713
525	728	1388	1947	2807
550	754	1436	2012	2899
575	780	1483	2076	2990
600	805	1529	2140	3080
625	830	1575	2203	3169
650	855	1620	2265	3257
675	880	1665	2326	3343
700	905	1709	2387	3429
725	929	1753	2447	3514
750	953	1796	2506	3598
775	977	1839	2565	3681
800	1001	1882	2623	3763
825	1024	1924	2681	3845
850	1048	1966	2738	3925
875	1071	2008	2795	4005
900	1094	2049	2851	4085

(Continued)

Notes: Adapted from Bridges (1982).
To convert cfs to cu m/sec, multiply by 0.0283.
To convert square miles to square kilometers, multiply by 2.6.

Table C1 (Concluded)

Drainage Area, square miles	Q_2, cfs	Q_5, cfs	Q_{10}, cfs	Q_{25}, cfs
925	1117	2090	2907	4163
950	1140	2131	2963	4241
975	1162	2171	3018	4319
1000	1185	2211	3072	4395
1050	1229	2290	3180	4547
1075	1251	2329	3234	4622
1100	1273	2368	3287	4697
1125	1295	2407	3339	4771
1150	1317	2446	3392	4844
1175	1338	2484	3444	4918
1200	1360	2522	3496	4990
1225	1381	2560	3547	5062
1250	1402	2597	3598	5134
1275	1423	2635	3649	5205
1300	1445	2672	3699	5276
1325	1465	2709	3750	5346

Table C2
Regression Equations, Region B

Drainage Area, square miles	Q_2, cfs	Q_5, cfs	Q_{10}, cfs	Q_{25}, cfs
25	215	472	703	1067
50	339	722	1060	1584
75	443	926	1347	1996
100	535	1105	1597	2352
125	620	1267	1823	2671
150	699	1417	2031	2964
175	774	1558	2225	3236
200	845	1691	2408	3492
225	913	1818	2582	3734
250	978	1939	2748	3965
275	1042	2056	2907	4187
300	1103	2169	3061	4400
325	1163	2278	3209	4605
350	1221	2384	3353	4804
375	1277	2487	3493	4996
400	1333	2588	3629	5184

(Continued)

Adapted from Bridges (1982).

Table C2 (Concluded)

Drainage Area, square miles	Q_2, cfs	Q_5, cfs	Q_{10}, cfs	Q_{25}, cfs
425	1387	2686	3762	5366
450	1440	2782	3891	5544
475	1492	2876	4018	5717
500	1544	2968	4142	5887
525	1594	3058	4263	6053
550	1644	3147	4382	6215
575	1692	3234	4499	6375
600	1740	3320	4614	6531
625	1788	3404	4727	6685
650	1835	3487	4838	6836
675	1881	3569	4947	6985
700	1926	3649	5055	7131
725	1971	3729	5161	7275
750	2016	3807	5265	7417
775	2060	3884	5369	7557
800	2103	3961	5470	7695
825	2146	4036	5571	7831
850	2189	4111	5670	7966
875	2231	4185	5768	8098
900	2273	4258	5865	8230
925	2314	4330	5961	8359
950	2355	4402	6056	8487
975	2395	4472	6150	8614
1000	2436	4543	6243	8739
1025	2476	4612	6335	8863
1050	2515	4681	6426	8985
1075	2554	4749	6516	9107
1100	2593	4816	6605	9227
1125	2632	4883	6694	9346
1150	2670	4950	6781	9464
1175	2708	5015	6969	9580
1200	2746	5081	6954	9696
1225	2784	5145	7040	9811
1250	2821	5210	7125	9924
1275	2858	5273	7209	10037
1300	2895	5337	7292	10149
1325	2931	5399	7375	10259
1350	2967	5462	7457	10369
1375	303	5524	7538	10478
1400	3039	5585	7619	10586

Table C3
Regression Equations, Region C

Drainage Area, square miles	Q_2, cfs	Q_5, cfs	Q_{10}, cfs	Q_{25}, cfs
25	13	9	7	5
50	23	16	12	10
75	32	22	18	14
100	41	28	23	19
125	49	34	27	23
150	57	39	32	27
175	65	45	36	31
200	72	50	41	34
225	80	56	45	38
250	87	61	50	42
275	94	66	54	45
300	101	71	58	49
325	108	76	62	53
350	115	81	66	56
375	121	86	70	60
400	128	90	74	63
425	135	95	78	67
450	141	100	82	70
475	147	104	86	4
500	154	109	90	77
525	160	114	94	80
550	166	118	98	84
575	173	123	101	87
600	179	127	105	90
625	185	132	109	94
650	191	136	113	97
675	197	141	116	100
700	203	145	120	104
725	209	149	124	107
750	215	154	127	110
775	221	158	131	113
800	227	162	135	117
825	232	166	138	120
850	238	171	142	123
875	244	175	145	126
900	250	179	149	129
925	255	183	153	132
950	261	188	156	136
975	267	192	160	139

(Continued)

Adapted from Bridges (1982).

Table C3 (Concluded)				
Drainage Area, square miles	Q_2, cfs	Q_5, cfs	Q_{10}, cfs	Q_{25}, cfs
1000	272	196	163	142
1025	278	200	167	145
1050	283	204	170	148
1075	289	208	174	151
1100	294	212	177	154
1125	300	216	181	157
1150	305	220	184	161
1175	311	224	187	164
1200	316	228	191	167
1225	322	232	194	170
1250	327	236	198	173
1275	333	240	201	176
1300	338	244	204	179
1325	343	248	208	182
1350	349	252	211	185
1375	354	256	215	188
1400	359	260	218	191

Part 2

Calculate overbank flow at the cross-section of interest. Two methods of overbank flow calculations are presented.

Method 1 – Manning's Equation. This method takes some engineering analysis and is recommended only for those familiar with the use of hydrologic and hydraulic equations.

A cross-sectional measurement must be taken near the wetland on the river that will possibly overflow its banks. These data are used with data for the channel slope and Manning's n to calculate the flow necessary to create overbank flow at the wetland cross-section.

(1) Measure the cross-section of the stream at the area of interest as shown in Figure C4.

(2) All calculations are done to encompass the cross-section at channel full at the point of wetland, as shown in Figure C4.

(3) Calculate the cross-section area in square feet A.

(4) Calculate the hydraulic radius R. This is defined as A/P, where P is the wetted perimeter.

(5) Calculate stream slope above area of interest SL in ft/ft.

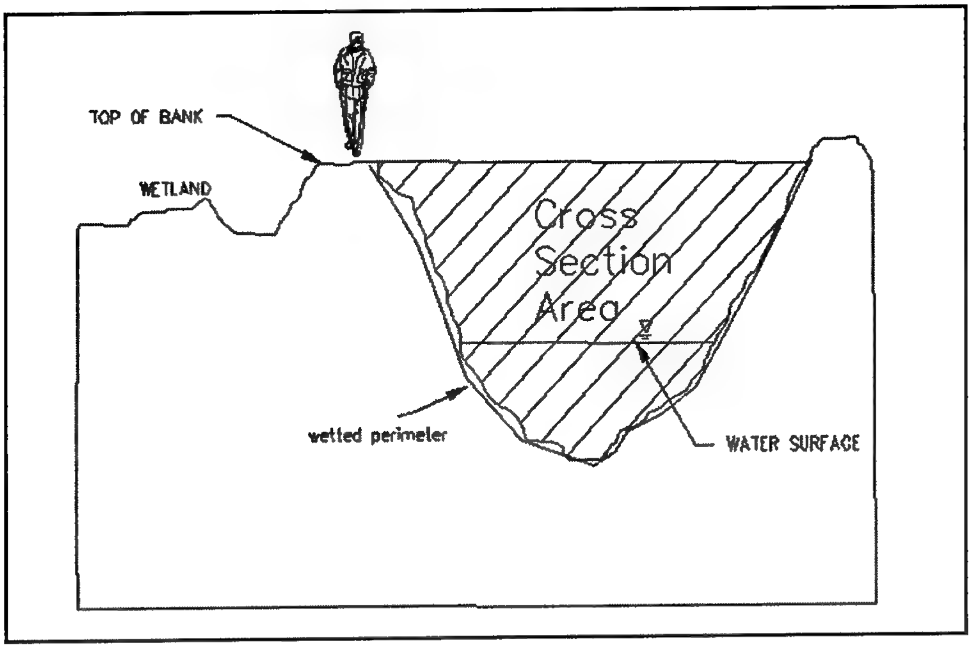


Figure C4. Stream cross-section measurement

(6) Use the Manning equation (Chow 1959; Gillen 1996) to calculate the $Q_{overbank}$ at point where stream flow is full and any more flow would go overbank and into the wetland. The equation definitions and values for n that are applicable to west-central Florida can be found in Gillen (1996). Portions of this report are contained at the end of this section.

A general form of the equation is:

$$Q_{overbank} = \frac{1.486 \, AR^{2/3} \, SL^{1/2}}{n}$$

where

$Q_{overbank}$ = cubic feet per second (cfs)

A = cross-section area in square feet

R = hydraulic radius defined as A/P where P is the wetted perimeter, in feet

SL = channel slope of the river above the wetland in ft/ft

n = Manning's friction factor, which can be estimated from Table C4. It is dimensionless.

Method 1 is a useful method but does require some engineering skill. The next method is presented for those who are less comfortable with the use of hydraulic equations.

Method 2 - Develop a Regional Rating Curve. This method is very simple and quickly allows the user to determine the overbank flow.

The challenge of determining overbank flow, $Q_{overbank}$, is approached by developing a relationship between $Q_{overbank}$ and cross-sectional area of the flooding source. $Q_{overbank}$ flow is the volume of flow in cfs that fills the river to its banks. Any more flow causes the river to spill over into the wetland of interest. Figure C4 is a schematic representing the cross section. To develop this curve, flow estimates were made using Manning's equation (as in Method 1). This equation uses cross-sectional area, roughness values (Manning's n), channel slope, and hydraulic radius to calculate flow. Data from 13 field measurements at reference wetlands were used to calculate Manning's flow for $Q_{overbank}$. The results were plotted with respect to cross section area and can be used to determine $Q_{overbank}$ from cross-section area measurements at any wetland in the region.

The user needs only to follow these steps:

Step 1. Determine drainage area of the major flooding source at site of interest (see Part 1).

Step 2. Measure the river cross section at channel-full depth (Figure C4).

Step 3. Use the regional curve (Figure C5) to get overbank flow, $Q_{overbank}$.

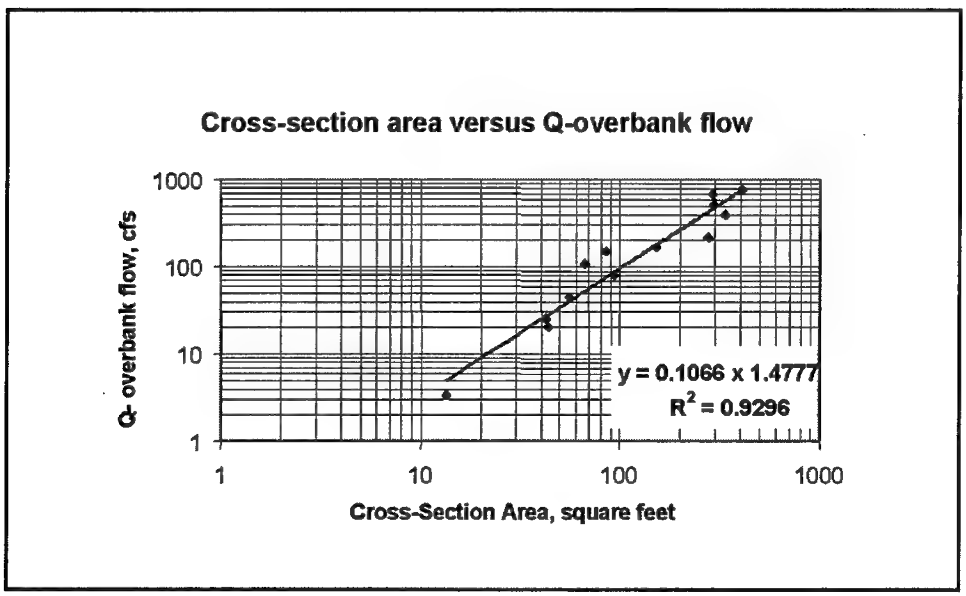


Figure C5. Regional curve for overbank flow

An accurate measurement of the cross-section area in the field is important. If it is not possible to measure the cross section of the river near the wetland, care must be taken to ensure that the measurement is related to

the section at the wetland. For instance, if the cross section is measured at a bridge downstream of the wetland, it is important that the area–the depth and width–represent the cross section at the wetland. There are many ways to do this, and it is not possible to develop a methodology that would be applicable in all situations.

One method to estimate the relationship between a cross section measured at a site upstream or downstream of the wetland site is presented:

(1) At the wetland - measure the distance from the water surface to the top of bank. This is a measurement of height - How high is the top of bank from the water surface? See Figure C6a.

(2) At the bridge - measure only the area (width and depth) of the section that is at or below the height above water surface measured in 1 above. See Figure C6b. Use this area as the cross-section area.

The user must use his/her judgment in transposing measurements of cross section not made at the wetland. For example, if the channel of the river at a bridge is 200 ft (61 m) wide but at the wetland it is only 50 ft (15 m) wide, it will be very difficult, if not impossible, to draw any relationship between the two measurements.

Part 3

Once the amount of flow that is necessary to inundate the wetland is determined (Part 2), it can be compared with the frequency of flood flows (Part 1).

This determines the frequency of overbank flooding, V_{FREQ}.

Relate $Q_{overbank}$ to Q_T to see how often flow will go overbank. For example, if $Q_{overbank}$ is 200 cfs (7 cu m/sec) and Q_T for a 2-year event (t=2) is 190 cfs (5 cu m/sec) it can be estimated that overbank flow will occur slightly more than every 2 years. The best way to compare the two flows, flood frequency and overbank, is to plot them. A good estimate of frequency of overbank flow can be determined by plotting each Q_T event, 2-, 5-, 10-, and 25- year flow with $Q_{overbank}$.

If the $Q_{overbank}$ is greater than the Q_{25}, which is the largest flow given in Tables C1-C3, then a subvariable index of 0.1 is assigned.

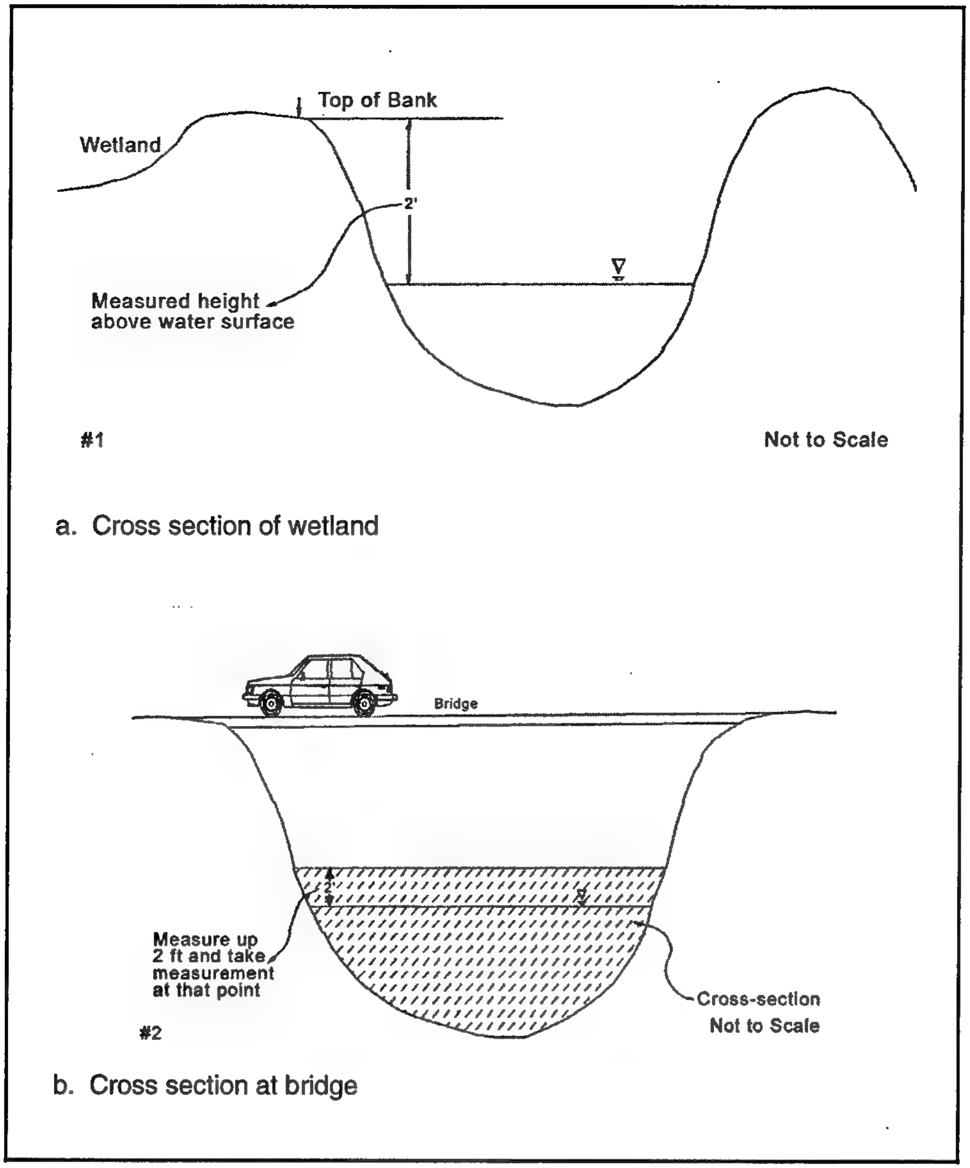


Figure C6. Cross section at wetland and at bridge

An Example Problem

Frequency of overbank flooding calculations (V_{FREQ}) example

The objective of determining the frequency of flooding at a particular site is to ascertain how often floodwaters reach the wetland surface. This is a critical consideration in assessing the functional capacity of riverine wetlands and can be accomplished in a number of ways. However, each method has shortcomings, which must be considered before utilizing a particular technique. This example will use the regional overbank flow curve developed (Method 2 in Part 2) and data from the Hillsborough River near Morris Bridge. This site is near a refrence wetland and also has a USGS gaging station nearby.

Source information for V_{FREQ} calculations

Locate the area of interest on a USGS Topographic Quadrangle (1:24,000) Map.

Determine drainage area using data from local USGS Water Resources Data records.

Example: V_{FREQ} calculations

The example site is located in Hillsborough County about 2.9 miles north of Thonotosassa, FL, 3.5 miles (5.6 km) upstream of Structure S-155, and 29 miles (47 km) upstream from the mouth. This site on the Hillsborough River at Morris Bridge is gage ID# 0230330.

The following steps follow the V_{FREQ} calculations.

Part 1

Method: (1) Determine the flood frequency Q_T for the 2-, 5-, 10-, and 25-year flows.

Step 1 - The USGS Topographic Quadrangle (1:24,000) Map is named Thonotosassa, FL. The wetland near the gage is the wetland of interest and the channel at the gage is assumed to be representative of the channel just downstream of the wetland of interest. Assume that the drainage area at the USGS gage is the same as near the wetland of interest. The Water Resources Data Document, Volume 3A, Southwest Florida Surface Water, for Water Year 1996 provides the information

on drainage area of 375 square miles (971 sq km) for the wetland watershed.

Step 2 - Locate the site on Figure C3. This will determine which area the wetland is in, A, B, or C. The Hillsborough River is in area A.

Step 3 - Use Table C1 with the drainage area of 375 square miles (971 sq km) to get:

Q_2 = 304 cfs (9 cu m/sec)
Q_5 = 605 cfs (17 cu m/sec)
Q_{10} = 867 cfs (25 cu m/sec)
Q_{25} = 1,278 cfs (36 cu m/sec)

Part 2

Method: (2) Determine the overbank flow, $Q_{overbank}$ using the regional curve.

Step 1 - Determine the drainage area at the wetland of interest. This has already been determined for Part 1, 375 square miles (971 sq km).

Step 2 - Measure the cross-section area at the wetland or bridge (Figure C6). In this example the cross section was measured at the wetland at Hillsborough River, Morris Bridge. Using a grid scheme to calculate an average area cross section area, A = 695 ft^2 (65 sq m).

Step 3 - Using the regional curve in Figure C5 (regional curve for overbank flow) to determine the overbank flow, $Q_{overbank}$ = 650 cfs (18 cu m/sec).

Part 3

$Q_{overbank}$ is greater than Q_5 but less than Q_{10}. Plot this out to get an estimate of V_{FREQ}. Figure C7 (recurrence interval flows) shows that the overbank flow occurs close to every 5 years. This is the value used to determine the variable subindex presented in the V_{FREQ} subindex explanation. Using Figure 5 (main text) the index value would be about 0.07.

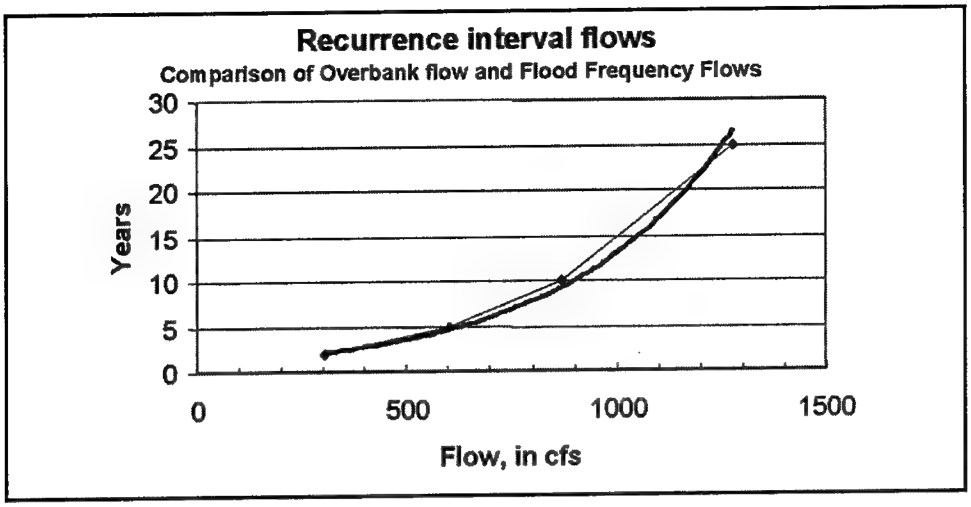


Figure C7. Comparing overbank flow and flood frequency flow

Procedure for Estimating Roughness Coefficients for West-Central Florida Streams[1]

Quantitative Methods

A general quantitative approach for determining roughness coefficients is to select a base *n* value for a straight, uniform, smooth channel in the natural materials of the streambed and banks and to add modifying values for channel-surface irregularity, channel-shape variation, obstructions, type and density of vegetation, and a degree of meandering. Cowan (1956) developed a procedure for estimating the effects of these factors to determine the value of *n* for a channel. The value may be computed by:

$$n - (n_b + n_1 + n_2 + n_3 + n_4)\, m$$

where

- n_b = base value of *n* for a straight, uniform, smooth channel with natural materials
- n_1 = correction factor for the effect of surface irregularities
- n_2 = value for variations in shape and size of the channel cross section
- n_3 = value for obstructions
- n_4 = value for the amount of vegetation and flow conditions
- m = correction factor for meandering of the channel.

1 Taken from Gillen (1996).

Gillen (1996) provides data for selecting a base n value for sand channels. Through his research he has determined that it is reasonable and appropriate to use a base value of 0.040 for streams in west-central Florida with the exception of the smoothest, nonvegetated sand channels.

Table C4 provides values for determining surface irregularities n_1; channel cross-section variations n_2; obstructions n_3; vegetation n_4; and degree of meandering n_5.

Table C4
Adjustment Values for Factors That Affect Channel Roughness

Channel Conditions	n Value Adjustment	Example
A. Surface Irregularity (n_1)		
Smooth	0.000	Compares to the smoothest channel attainable in a given bed material.
Minor	0.01-0.005	Compares to carefully dredged channels in good condition but having slightly eroded or scoured side slopes.
Moderate	0.006-0.010	Compares to dredged channels having moderate to considerable bed roughness and moderately sloughed or eroded side slopes.
Severe	0.011-0.020	Badly sloughed or scalloped banks of natural stream; badly eroded or sloughed sides of canals or drainage channels; unshaped, jagged, and irregular surfaces of channels in rock.
B. Channel Cross-Section Variations (n_2)		
Gradual	0.000	Size and shape of channel cross sections change gradually.
Alternating occasionally	0.001-0.005	Large and small cross sections alternate occasionally, or the main flow occasionally shifts from side to side owing to changes in cross-sectional shape.
Alternating	0.010-0.015	Large and small cross sections alternate frequently, or the main flow frequently shifts from side to side owing to changes in cross-sectional shape.
C. Obstructions (n_3)		
Negligible	0.000-0.004	A few scattered obstructions, which include debris deposits, stumps, exposed roots, logs, piers, or isolated boulders that occupy less than 5 percent of the cross-section area.
Minor	0.005-0.015	Obstructions occupy less than 15 percent of the cross-sectional area and the spacing between obstructions is such that the sphere of influence around one obstruction does not extend to the sphere of influence around another obstruction. Smaller adjustments are used for curved smooth-surfaced objects that are used for sharp-edged angular objects.
Appreciable	0.020-0.030	Obstructions occupy more than 50 percent of the cross-section area or the space between obstructions is small enough to cause the effects of several obstructions to be additive, thereby blocking an equivalent part of a cross section.
Severe	0.040-0.050	Obstructions occupy more than 50 percent of the cross-section area or the space between obstructions is small enough to cause turbulence across most of the cross section.

(Continued)

Modified from Gillen (1996).

Table C4 (Concluded)

Channel Conditions	n Value Adjustment	Example
D. Vegetation (n_4)		
Negligible	0.000	Any type or density of vegetation growing on the banks of the channels more than 100 ft wide with less than 25 percent of the wetted perimeter vegetated and no significant vegetation along channel bottoms. Mowed grass or vetch on banks of channels over 50 ft (15 m) wide. (Could be applicable to narrower channels)
Small	0.02-0.010	Dense growth of flexible turf grass, such as Bermuda, or weeds growing where the average depth of flow is at least two times the height of the vegetation; supple tree seedlings such as willow, swamp dogwood, or button bush growing where the average depth of flow is at least three times the height of the vegetation. Dense woody brush, soft stemmed plants, a few mature trees, that cover 25 to 50 percent of the wetted perimeter on the banks of channels from 100 to about 250 ft (30 to about 76 m) wide.
Medium	0.010-0.025	Turf grass growing where the average depth of flow is from one to two times the height of the vegetation; moderately dense stemmy grass, weeds, or tree seedlings growing where the average depth of flow is from two to three times the height of the vegetation; brushy, moderately dense vegetation, similar to 1-to-2-year-old willow, swamp dogwood, carolina ash, or button bush trees in the dormant season, growing along the banks and no significant vegetation along the channel bottoms where the hydraulic radius exceeds 2 ft (0.6 m).
Large	0.025-0.050	Turf grass growing where the average depth of flow is about equal to the height of the vegetation; 8-to-10-year-old willow, swamp dogwood, carolina ash, or button bush trees intergrown with some weeds and brush (none of the vegetation is foliage) where the hydraulic radius exceeds 2 ft (0.6 m); bushy willow about 1 year old intergrown with some weeds alongside slopes (all vegetation in full foliage) and no significant vegetation along channel bottoms where the hydraulic radius is greater than 2 ft (0.6 m).
Very Large	0.050-0.100	Turf grass growing where the average depth of flow is less than half the height of the vegetation; bushy willow, swamp dogwood, carolina ash, or button bush trees about 1 year old intergrown with weeds along side slopes (all vegetation in full foliage) or dense cattails growing along channel bottom; trees intergrown with weeds, brush (all vegetation in full foliage).
E. Degree of Meadering (n_5)		
Minor	1.00	Ratio of the channel length to valley length is 1.0 to 1.2.
Appreciable	1.15	Ratio of the channel length to valley length is 1.2 to 1.5.
Severe	1.30	Ratio of the channel length to valley length is greater than 1.5.

Appendix D
Reference Wetland Data

Table D1, which is included in the electronic version only, contains the data collected at reference wetland sites in west-central peninsular Florida.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT	2. REPORT TYPE	3. DATES COVERED *(From - To)*
January 2003	Final report	

4. TITLE AND SUBTITLE
A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Low-Gradient, Blackwater Riverine Wetlands in Peninsular Florida

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
See reverse

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER
32985

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
See reverse

8. PERFORMING ORGANIZATION REPORT NUMBER
ERDC/EL TR-03-3

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Corps of Engineers
Washington, DC 20314-1000

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES
Appendix D was published in electronic version posted on Internet only.

14. ABSTRACT
The Hydrogeomorphic (HGM) Approach is a collection of concepts and methods for developing functional indices and subsequently using them to assess the capacity of a wetland to perform functions relative to similar wetlands in a region. The approach was initially designed to be used in the context of the Clean Water Act Section 404 Regulatory Program permit review sequence to consider alternatives, minimize impacts, assess unavoidable project impacts, determine mitigation requirements, and monitor the success of mitigation projects. However, a variety of other potential applications for the approach have been identified including determining minimal effects under the Food Security Act, designing mitigation projects, and managing wetlands.

This report uses the HMG Approach to develop a Regional Guidebook for assessing the functions of low-gradient blackwater riverine wetlands in peninsular Florida. The report begins with a characterization of low-gradient blackwater riverine wetlands in peninsular Florida, then discusses (a) the rationale used to select functions, (b) the rationale used to select model variables and metrics, (c) the rationale used to develop assessment models, and (d) the data from reference wetlands used to calibrate model variables and assessment models. Finally, it outlines an assessment protocol for using the model variables and functional indices to assess low-gradient blackwater riverine wetlands in peninsular Florida.

15. SUBJECT TERMS
See reverse.

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE		249	19b. TELEPHONE NUMBER *(include area code)*
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED			

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. 239.18

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15. SUBJECT TERMS (Concluded).

404 Regulatory Program	Impact analysis
Assessment	Index
Blackwater	Indicators
Classification	Landscape
Clean Water Act	Method
Ecosystem	Mitigation
Evaluation	Model
Florida	National Action Plan
Function	Peninsular Florida
Functional assessment	Procedure
Functional profile	Reference wetlands
Geomorphology	Restoration
HGM Approach	Wetland assessment
Hydrogeomorphic	Wetland functions
Hydrogeomorphic Approach	Wetlands
Hydrology	Value